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PHYSICAL DATA ON CERTAIN ALLOYS
FOR HIGH TEMPERATURE APPLICATIONS

By A. E. White, J. W. Freeman, and F. B. Rote
University of Michigan

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

 REPORT

PHYSICAL DATA ON CERTAIN ALLOYS FOR
HIGH TEMPERATURE APPLICATIONS

By A. E. White, J. W. Freeman, and F. B. Rote

SUMMARY

The data given in this report constitute a summary of the physical properties of 120 samples of metal alloys, representing 86 different compositions which have been investigated for their suitability as turbosupercharger wheel materials. The reported data include the chemical composition, fabrication procedure, tensile-test and hardness values at room temperature, and tensile and rupture-test characteristics at 1200° F. Comments of contributors of the test materials concerning the workability and machinability of the alloys have been included.

Since the data obtained are very extensive, comparison sheets, given in Figures 1, 2, and 3, are included. In these sheets the chemical analyses, processing procedures, hardness values, yield strengths at room temperature, stresses for rupture in 100 and 1000 hours at 1200° F., and ductility characteristics are presented in a manner which permits comparison of the properties of the various alloys.

INTRODUCTION

In October, 1941 the National Advisory Committee for Aeronautics retained the Department of Engineering Research of the University of Michigan to conduct an experimental metallurgical investigation to find improved materials for use in exhaust gas turbines. The Committee also appointed a Special Subcommittee on Metals for Turbosupercharger Wheels and Buckets which is charged with directing the Committee's activities in the field. The membership of the Subcommittee is as follows:

Mr. W. L. Badger, General Electric Company, Chairman
Mr. Lewis S. Bergen, Crucible Steel Company
Mr. V. Browne, Allegheny Ludlum Steel Corporation
Mr. C. T. Evans, Jr., Universal-Cyclops Steel Corporation
Mr. Russell Franks, Union Carbide & Carbon Research Laboratories, Inc.

Dr. Marcus A. Grossmann, Carnegie-Illinois Steel Corporation
Dr. George W. Lewis, NACA (ex officio)
Mr. Russell G. Robinson, NACA (ex officio)

An advance confidential report entitled "Physical Data on Certain Alloys for High Temperature Applications" was compiled by the Coordination Office of the National Advisory Committee for Aeronautics in October, 1942 based upon data obtained by the University of Michigan up to that time. Nitrogen analyses have been made for several of the materials presented in the October, 1942 report, and in addition the names of several of the alloys have been changed to prevent confusing them with materials tested later in the program. For these reasons it was believed advisable to include in this present report all materials that have been tested at the University of Michigan in this research. Therefore this present report supersedes the report prepared by the Committee in October, 1942.

The investigation is being conducted for the purpose of developing alloys with the best possible combination of load-carrying ability at 1200° F., and yield strength at room temperature. These qualities were selected since they are indicative of the properties required in materials for turbosupercharger wheels.

Full cognizance is taken of the importance of developing alloys which contain the least possible amount of strategic metals and yet have the necessary properties to withstand turbosupercharger wheel service. Forgeability and machinability, likewise, are receiving consideration. No information is presented on such factors as weldability, and production practice, although they have received consideration by the Subcommittee.

The results of the investigation indicate that both the load-carrying ability at 1200° F. and the room-temperature properties of most of the alloys can be increased by mechanically working the alloys at temperatures below the normal hot-working temperatures. Since it appears that this factor has more influence than comparatively wide variations in chemical composition for a given type of alloy, the research is now being extended to include an intensive investigation on the effect of treatment on the strength characteristics of several materials that are shown by these present tests to be of special interest.

The materials used in this investigation were supplied by the Allegheny Ludlum Steel Company, Carnegie-Illinois Steel Corporation, Crucible Steel Company, General Electric Company, International Nickel Company, Inc., Timken Roller Bearing Company, Union Carbide and Carbon Research Laboratories, Inc., and Universal-Cyclops Steel Corporation. The cooperation of these steel companies in preparing experimental and production steels contributed greatly to the investigation.

The steel manufacturers who contributed specimens for testing in NACA research on high temperature materials have indicated that they will be pleased to discuss the alloys described in this report with any qualified person acting as a representative of a contractor to the United States Government. Therefore, if additional information on these alloys is required, it is suggested that such information be requested from the proper manufacturer.

TABULATED DATA

The information given in the following pages of this report includes (1) the chemical composition of the sample, as reported by the manufacturers; (2) the fabrication procedure; (3) the hardness at room temperature before and after completion of the longest duration time-for-rupture test; (4) short-time tensile properties at room temperature and at 1200° F; and (5) the rupture-test data, including ductility values, obtained at 1200° F. In addition, the stresses to cause rupture in 1, 10, 100, and 1000 hours at 1200° F. are given.

The rupture strengths were determined by logarithmic plots of the stress versus rupture-time data. Even though the duration of the longest test may have been considerably less than 1000 hours, the values reported are based on extrapolations which have proved to be reasonably reliable for this test. In certain cases the rupture tests were not continued for time periods longer than 200 hours because the samples were not considered good enough to warrant further testing. The stress-rupture time values from a few samples gave a scatter of points instead of the usual straight line when plotted to logarithmic coordinates. In such cases the reported rupture strengths were obtained from the best average straight line through the points.

Figures 1, 2, and 3 on pages 252, 253, and 254 summarize the data for the samples from each manufacturer. In addition to compositions and fabrication procedures, the hardness and yield stresses at room temperature, stresses for rupture in 100 and 1000 hours at 1200° F., and ductility characteristics are presented in these figures. These physical properties were selected for presentation because they permit evaluation of the suitability of the alloys for turbosupercharger wheel service.

Comments on Data

The manufacturers of the experimental materials from which the data were obtained submitted comments on the forgeability and machinability of their alloys. This information has been incorporated in the data sheets. It is extremely difficult to evaluate these

properties for even one application of the alloys, and thus all statements contained in this report in regard to forgeability and machinability must be considered as relative to other similar high-strength alloys.

The reader will note that most of the alloys described herein have been handled only on an experimental basis. The manufacturer, therefore, in describing an alloy as commercially forgeable and machinable, may not have been able to take into account the difficulties that might be encountered if that alloy is produced on a "tonnage" basis.

In every case the data presented in this report are the results of a series of tests on one particular heat of alloy with one particular sequence of treatments. It is intended that this report be only a factual presentation of test results plus comments on workability supplied by the manufacturers. In the materials obtained from small experimental induction heats, it should be recognized that production heats processed under commercial practice may have a different level of properties.

In those cases where erratic stress versus rupture-time data were obtained, the sample may have been nonuniform. There are, however, certain alloys in which a scatter of results is characteristic of the material and is believed to be associated with structural changes in the metal during testing. The agreement between the duplicate tensile-test results is a good measure of the uniformity of the material. For this reason the individual test results have been used in Figures 1, 2, and 3.

The dimensions of the test specimens used in the investigation are given in Figure 4 on page 255. The rupture test specimen was arbitrarily selected by the Subcommittee as being of convenient size to use in making a large number of tests. These specimens were taken from the bar stock at a point midway between the center and surface.

The tests were run in accordance with ASTM recommended procedure for tension testing at room temperature and at elevated temperatures. The yield strengths and proportional limits were obtained from stress-strain curves plotted from strain data obtained with an extensometer system having a sensitivity of 0.000003 inch per inch in a two-inch gage section.

In a few cases the tensile properties are incomplete because insufficient bar stock was available for the necessary specimens.

ANALYSIS OF DATA

The objective of the investigation was to develop metals with a combination of high rupture strength at 1200° F. and high yield strength at room temperature.

The most important factor in determining the yield strength appeared to be fabrication procedure. Variations in chemical composition did not seem to have much effect except for carbon content in such alloys as 19-9W-Mo. With one exception, yield strengths at room temperature in excess of 100,000 pounds per square inch combined with high rupture strength at 1200° F. were developed only by mechanical working of the metal at intermediate temperatures. This "hot-cold" work also resulted in an increase in rupture strength at 1200° F. over that of the annealed condition. The possible range in both yield and rupture strengths of a given nominal composition resulting from variations in the fabrication procedure was generally more than that caused by wide differences in chemical composition.

The data presented in this report indicate that the effects of variations in fabrication procedure may be summarized as follows:

1. There appears to be an optimum amount of "hot-cold" work for each analysis at each temperature.
2. The highest properties are probably associated with the optimum amount of "hot-cold" work at some one temperature for each analysis.
3. The thermal history, particularly the inclusion or omission of a solution heat treatment, appears to affect the properties.

Variations in properties are apparently caused by differences in fabrication procedures for the following reasons:

1. Most of the alloys are subject to complex structural reactions of the precipitation hardening type which, in part, control the properties.
2. The strength properties are also influenced by the amount of strain hardening obtained by "hot-cold" work.
3. Variations in the amount and temperature of "hot-cold" work and in the times, temperatures, and sequences of thermal treatments result in variations of the structural reaction characteristics and residual strain hardening.

4. In addition to the above factors, there probably are additional variations which the data given in this report have not taken into consideration.

No systematic variation in properties with variations in composition has been noted in the data given in this report. The following compositions, however, exhibited outstanding strength properties:

1. High alloyed materials designated 6MM, 2MM, 1M, 16-25-6, N153, N154, N155, N156 and Age Hardenable Inconel. Many of the modifications of these alloys also has as high or higher properties.
2. Low alloyed materials designated as 19-9W-Mo and 4Mn-18Cr-4Ni types and their modifications. These had very high rupture strengths, but somewhat low yield strengths.
3. A heat-treatable alloy designated as Age Hardenable Inconel. This alloy was the only one found to develop high rupture strength and high yield strength without mechanical working at intermediate temperature.

It is important that the following factors be considered in appraising the above outstanding alloys:

1. Other alloys may develop equal or better properties under the proper, but as yet unknown, fabrication procedure.
2. It is not known whether the reported properties represent the ultimate which may be obtained in the outstanding alloys.
3. The degree of reproducibility of their properties, particularly in wheel forgings, is unknown except for such alloys as 16-25-6 in which considerable production experience is available.
4. Most of the alloys in the lists have been handled only in small experimental heats as bar stock.
5. With the exception of Age Hardenable Inconel, the high yield strengths were developed by approximately 25 percent reduction in area by rolling at 1200 to 1700° F. Because of their good high-temperature strength, these alloys are very resistant to deformation in this temperature range. It will be difficult, therefore, to obtain this amount of reduction in commercial practice. Certain of the samples were prepared by methods which were, possibly, more representative of ordinary commercial practice than the alloys giving the highest strength

properties. For this reason the lower properties of such apparently less promising alloys may be more representative of those which can be obtained by ordinary commercial practice.

List of Alloys

	<u>Alloy</u>	<u>Page</u>
Allegheny Ludlum Steel Corporation	S495	12
	S497	14
	AM	16
	BM	18
	Ticonium 1014	20
Crucible Steel Company of America	Halcomb 217	22
	4274	24
	4276	26
	4277	28
	4273	30
	4480	32
	4481	34
	4275	36
	234-A-5	38
	4237	40
	Rezistal VR	42
Carnegie-Illinois Steel Corporation	L2-T1	44
	L2-T2	46
	L2-T3	48
	L3-T1	50
	L3-T2	52
	L3-T3	54

List of Alloys (Cont'd.)

	<u>Alloy</u>	<u>Page</u>
Carnegie-Illinois Steel Corporation Cont'd.	2605	56
	2606	58
	2607	60
	2608	62
	L4	64
	L7	66
	L1-T1	68
	L1-T2	70
	L1-T3	72
International Nickel Company, Inc.	Age Hardenable Inconel	74
	Nimonic 80	76
Universal-Cyclops Steel Corporation	17W-Annealed	78
	17W-Hot Rolled	80
	17W-"Cold" Worked	82
	17W-Hot Worked	84
	17W-"Cold" Worked (R1644)	86
	17W-NM	88
	17W-Cb	90
	Low Carbon 17W-Annealed	92
	Low Carbon 17W-Hot Worked	94
	Low Carbon 17W-"Cold" Worked	96
	Timken 16-25-6 Annealed	98
	Timken 16-25-6 Hot Worked	100
	Timken 16-25-6 "Cold" Worked	102
	Gamma Columbium-Annealed	104
	Gamma Columbium-Hot Rolled	106
	Gamma Columbium-Hot Worked	108
	Gamma Columbium-"Cold" Worked	110
	Non-magnetic	112
	E-447	114

List of Alloys (Cont'd.)

	<u>Alloy</u>	<u>Page</u>
Universal-Cyclops Steel Corporation Cont'd.	R-1038 Annealed	116
	R-1038 "Cold" Worked	118
	18-14 S-Mo	120
	19-9 W-Mo (B7030)	122
	19-9 W-Mo (R1802)	124
	19-9 W-Mo (R1956)	126
	19-9 W-Mo HC2	128
	19-9 W-Mo M	130
	19-9 W-Mo 4	132
	19-9 W-Mo 4M	134
	4	136
	9	138
	9M	140
	5	142
	5M	144
	5MM	146
	1	148
	1M	150
	8	152
	8M	154
	2	156
	2M	158
	2MM	160
	6	162
	6M	164
	6MM	166
Union Carbide and Carbon Research Laboratories, Inc.	H350	168
	1073-Annealed (H350)	170
	1073 (H350)	172

List of Alloys (Cont'd.)

	<u>Alloy</u>	<u>Page</u>
Union Carbide and Carbon Research Laboratories, Inc. Cont'd.	H351	174
	H357	176
	H479	178
	H496	180
	H414	182
	H353	184
	H412	186
	H497	188
	H354	190
	H416	192
	H417	194
	H419	196
	H418	198
	H729	200
	H480	202
	H355	204
	H413	206
	H359	208
	H439	210
	H630 (Low carbon Gamma	212
	H631 Columbium)	214
	H624	216
	H625	218

List of Alloys (Cont'd.)

	<u>Alloy</u>	<u>Page</u>
Union Carbide and Carbon Research Laboratories, Inc., Cont'd.	H626	220
	H627	222
	H628 (H419)	224
	H629 (H419)	226
Universal-Cyclops Steel Corporation and Union Carbide and Carbon Research Laboratories, Inc.	N153-Annealed	228
	N153-Hot Worked	230
	N153-"Cold" Worked	232
	N154-Annealed	234
	N154-Hot Worked	236
	N154-"Cold" Worked	238
	N155-Annealed	240
	N155-Hot Worked	242
	N155-"Cold" Worked	244
	N156-Annealed	246
	N156-Hot Worked	248
	N156-"Cold" Worked	250

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ALLOY S495

MANUFACTURER Allegheny Ludlum Steel Corporation

COMPOSITION 0.48% C, 0.56% Si, 0.55% Mn, 13.68% Cr, 20.06% Ni,
4.14% Mo, 3.36% W, 4.59% CbTREATMENT Melted in an induction furnace as a 30 pound heat;
cast in 3-inch square ingot and forged at 2200° F to
0.9-inch square bar. Cooled in air, reheated to
1400° F and forged to 3/4-inch square bar.

HARDNESS 290-294 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	146,750	83,000	135,000	35,000	7.5	30.7
	147,750	80,000	136,000	35,000	6.0	21.7
1200	87,625		72,200	37,500	24.0	34.3
	75,000		60,500	32,500	23.0	25.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
78,000	0.13	11.0	24.5
70,000	0.50	21.0	39.4
62,000	1.35	26.0	40.8
42,000	21.5	22.0	27.2
32,000	200.	15.0	16.1
26,000	854.	7.0	10.8

Vickers Hardness: As received - 292
After 200 hours at 1200° F - 294

Alloy S495 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	63,000
10	47,000
100	35,000
1000	26,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY After initial forging can be hot-rolled and subsequently cold rolled or cold drawn successfully.

MACHINABILITY Commercially machinable.

NACA

ALLOY S497

MANUFACTURER Allegheny Ludlum Steel Corporation

COMPOSITION 0.42% C, 0.61% Si, 0.47% Mn, 13.68% Cr, 19.50% Ni,
19.00% Co, 3.84% Mo, 4.28% W, 4.41% Cb

TREATMENT Melted in an electric arc furnace as a 10 ton heat.
Cast in 900-pound ingot 8 inches square. Heated to
2200° F and forged on hammer to 0.9-inch square bar.
Reheated to 1400° F and forged to 3/4-inch square bar.

HARDNESS 311 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	154,750	101,000	138,500	57,500	10.5	25.5
	152,500	102,500	136,000	57,500	12.0	26.0
1200	96,750		75,200	15,000	20.0	39.3
	103,625		89,800	15,000	22.0	25.9
	99,625		87,600	27,500	20.0	25.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
88,000	0.38	11.0	29.3
78,000	1.65	22.0	38.5
50,000	60.5	10.0	6.1
38,000	360.	11.0	12.6
33,000	1099.	6.0	7.4

Vickers Hardness: As received - 314
After 1099 hours at 1200° F - 331

Alloy S497 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	80,000
10	60,000
100	45,000
1000	33,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Metal must be hot-forged from the ingot to a relatively small cross section before it can be hot-rolled or subsequently cold rolled or cold drawn.

MACHINABILITY Commercially machinable.

NACA

ALLOY AM*

MANUFACTURER Allegheny Ludlum Steel Corporation

COMPOSITION 0.40% C, 0.375% Si, 0.41% Mn, 17.83% Cr, 4.08% Ni,
2.62% Mo, 0.018% P, 0.019% S, 0.12% N₂.TREATMENT Melted in an electric arc furnace in a 900 pound heat.
Cast in a 7- by 7-inch ingot weighing approximately
750 pounds. Ingot heated to about 2100° F and rolled
to 5 $\frac{1}{2}$ -inches square billet on a 2 high reversing
blooming mill. Reheated and rolled on a 12-inch rod
mill to 0.94-inch square bar. Reduced at 1200° F to a
3/4-inch square bar. Annealed at 2100° F and air cooled.

HARDNESS 209 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	128,500	62,750	72,300	52,500	47.0	34.2
	121,500	60,000	70,000	42,500	40.0	32.3
1200	76,500		32,000	20,000	22.0	24.9
	77,000		33,500	17,500	22.0	25.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
65,000	0.42	11.0	15.1
55,000	1.18	6.0	19.6
35,000	29.7	1.0	1.0
30,000	225.7	2.0	6.7
27,000	312.	1.0	12.1

Vickers Hardness: As received - 224
After 312 hours at 1200° F - 429

Alloy AM continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	58,000
10	42,500
100	31,700
1000	23,400

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Can be rolled either hot or cold with ease. Does not require forging at any stage.

MACHINABILITY In the austenitic or annealed condition, machinability is about the same as for similar austenitic steels but in the hardened condition is extremely difficult to machine. Further study of heat treatment may improve this condition.

OTHER NOTES Metal is of interest for use in the cast condition.

*Alloys AM and BM are from the same heat and differ only in processing procedure.

NACA

ALLOY BM*

MANUFACTURER Allegheny Ludlum Steel Corporation

COMPOSITION 0.40% C, 0.375% Si, 0.41% Mn, 17.83% Cr, 4.05% Ni,
2.62% Mo, 0.018% P, 0.019% S, 0.12% N₂.TREATMENT Melted in an electric arc furnace in a 900 pound heat.
Cast in a 7- by 7-inch ingot weighing approximately
750 pounds. Ingot heated to about 2100° F and rolled
to 5¹/₂-inch square billet in 2 high reversing blooming
mill. Reheated and rolled on a 12-inch rod mill to
0.94-inch square bar. Reduced at 1200° F to a 3/4-inch
square bar.

HARDNESS 418 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	207,000	116,250	160,250	87,500	13.0	21.6
	203,500	117,500	161,000	85,000	11.0	11.7
1200	96,500		75,500	45,000	16.5	28.4
	94,875		-----	-----	17.0	31.7

STRESS-RUPTURE DATA AT 1200° F **

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
60,000	7.16	13.0	10.3
40,000	30.8	7.0	10.9
30,000	153.	13.0	11.0
20,000	644.	18.0	19.0

Vickers Hardness: As received - 423
After 644 hours at 1200° F - 189

Alloy BM continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	-----
10	55,000
100	32,000
1000	19,000

COMMENTS SUPPLIED BY THE MANUFACTURER

- FORGEABILITY** Can be rolled either hot or cold with ease. Does not require forging at any stage.
- MACHINABILITY** In the austenitic or annealed condition, machinability is about the same as for similar austenitic steels but in the hardened condition is extremely difficult to machine. Further study of heat treatment may improve this condition.
- OTHER NOTES** Metal is of interest for use in the cast condition.

*Alloys AM and BM are from the same heat and differ only in processing procedure.

**Rupture test specimens for this metal were 0.300-inch diameter with a 1-inch gage length.

NACA

ALLOY "Ticonium" (1014)

MANUFACTURER Allegheny Ludlum Steel Corporation

COMPOSITION 0.088% C, 0.272% Si, 0.80% Mn, 22.96% Cr, 35.00% Ni,
30.84% Co, 5.81% Mo, 0.008% P, 0.014% STREATMENT Melted in electric arc furnace, cast in 6- by 10-inch
ingot weighing 358 pounds. Heated to 2150° F and forged
to a 1-inch square bar. Reheated to 1400° F and forged
to 3/4-inch square bar between 1400 and 1200° F.

HARDNESS 385 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	182,250	126,500	161,250	90,000	15.0	49.3
	183,750	131,000	165,000	100,000	15.0	49.5
1200	117,125		92,500	20,000	6.0	15.0
	121,500		100,000	25,000	2.0	14.3

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
100,000	1.37	6.0	9.7
87,000	3.68	2.0	7.8
60,000	86.0	4.0	3.8
50,000	113.	7.0	8.5
42,000	210.	5.0	7.2
33,000	967.	3.0	7.3

Vickers Hardness: As received - 382
After 967 hours at 1200° F - 347

Alloy "Ticonium" (1014) continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	100,000
10	84,000
100	52,500
1000	33,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Extremely difficult to forge. Requires special technique and a number of reheatings.

MACHINABILITY Difficult to machine but can be machined with regular high speed tools.

NACA

ALLOY Halcomb 217

MANUFACTURER Crucible Steel Company of America

COMPOSITION 0.58% C, 1.08% Si, 0.54% Mn, 7.56% Cr, 7.87% W

TREATMENT Melted in a commercial arc furnace, 12-inch square fluted ingot. Alloy was hammer clogged at 2050 to 2100° F to $6\frac{1}{2}$ inches square, reheated and clogged to $4\frac{1}{2}$ inches square, then annealed. Mill reclogged at 2000 to 2050° F to $1\frac{5}{8}$ inches square, annealed and conditioned. Hammered at approximately 1950° F to a $\frac{3}{4}$ -inch square bar. Annealed by slow cooling from 1650° F. Normalized at 2050° F for 3 minutes, then drawn at 1300° F for 1 hour.

HARDNESS 330 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02 %	0.2 %			
80	173,500	105,000	122,000	92,500	11.5	17.7
	174,500	106,000	128,000	90,000	12.0	19.5
1200	53,125		37,500	10,000	40.5	79.5
	47,625		36,500	10,000	41.0	77.3

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
40,000	0.58	38.0	74.4
34,000	1.50	46.0	76.8
20,000	72.0	42.0	47.4
15,000	163.	50.0	49.7
13,000	243.	29.0	41.0

Vickers Hardness: As received - 362
After 243 hours at 1200° F - 259

Alloy Halcomb 217 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	37,200
10	29,000
100	18,000
1000	7,900

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY About equal to 18-4-1 high speed steel.

MACHINABILITY Commercially machinable.

NACA

ALLOY 4274

MANUFACTURER Crucible Steel Company of America

COMPOSITION 1.06% C, 0.30% Si, 0.59% Mn, 13.18% Cr, 12.87% Ni,
0.62% Mo, 2.18% WTREATMENT 30 pound induction furnace ingot. Forged 1950-
1900° F to 3/4 inch square. Cooled to 1300-1200° F
and finished with a few blows.

HARDNESS 300 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	148,000	81,000	107,500	52,500	17.5	25.8
	148,125	79,000	106,000	52,500	17.0	23.0
1200	93,750		71,900	45,000	16.0	18.4
	97,750		71,250	50,000	5.0	10.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
80,000	1.42	5.0	6.2
75,000	3.32	4.0	4.9
50,000	108.	6.0	10.9
40,000	337.	6.0	8.5
37,000	401.	6.0	6.2

Vickers Hardness: As received - 318
After 401 hours at 1200° F - 352

Alloy 4274 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	82,000
10	69,000
100	51,000
1000	31,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty as a small induction heat.
No information on forgeability of commercial heats.

MACHINABILITY Metal turned and threaded with difficulty.

NACA

ALLOY 4276

MANUFACTURER Crucible Steel Company of America

COMPOSITION 0.53% C, 0.45% Si, 12.34% Mn, 20.39% Cr, 1.88% W, 2.31% Mo

TREATMENT 30 pound induction furnace ingot. Forged 1950-1900° F to 3/4 inch square. Cooled to 1300-1200° F and finished with a few blows.

HARDNESS 280 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	133,750	57,500	93,125	27,500	15.5	24.1
	135,750	45,625	87,500	22,500	14.0	16.3
1200	51,500		38,125	15,000	40.0	54.1
	56,000		38,000	12,500	24.0	29.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
45,000	1.00	36.0	46.0
38,750	6.55	45.0	55.7
28,000	63.0	44.0	58.7
20,000	498.0	35.0	47.8

Vickers Hardness: As received - 291
After 498 hours at 1200° F - 463

Alloy 4276 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	45,000
10	37,500
100	26,000
1000	18,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty as a small induction heat.
No information on forgeability of commercial heats.

MACHINABILITY Metal turned and threaded without difficulty.

NACA

ALLOY 4277

MANUFACTURER Crucible Steel Company of America

COMPOSITION 1.05% C, 0.59% Si, 12.34% Mn, 20.43% Cr, 2.22% Mo,
1.92% WTREATMENT 30 pound induction furnace ingot. Forged 1950-1900° F
to 3/4 inch square. Cooled to 1300-1200° F and
finished with a few blows.

HARDNESS 340 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	151,000	63,000	102,500	42,500	2.0	1.9
	156,500	65,000	102,200	40,000	5.0	5.8
1200	82,750		58,750	35,000	16.5	20.6
	81,250		68,750	37,500	7.5	2.3

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
76,000	0.68	11.0	19.0
68,000	4.33	25.0	27.7
56,000	111.0	14.0	31.8
50,000	139.0	16.0	22.4
42,000	684.0	9.0	13.3

Vickers Hardness: As received - 366
After 684 hours at 1200° F - 467

Alloy 4277 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	74,000
10	65,000
100	56,000
1000	39,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty as a small induction heat.
No information on forgeability of commercial heats.

MACHINABILITY Metal turned and threaded with difficulty.

NACA

ALLOY 4273

MANUFACTURER Crucible Steel Company of America

COMPOSITION 0.23% C, 0.31% Si, 3.98% Mn, 18.41% Cr, 4.10% Ni, 3.11% Mo

TREATMENT 30 pound induction furnace ingot. Forged 1950-1900° F to 3/4 inch square. Cooled to 1500-1200° F and finished with a few blows.

HARDNESS 256 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	137,750	78,125	96,875	55,000	32.0	42.8
	137,250	70,000	90,000	55,000	25.0	24.1
1200	70,250		53,750	30,000	34.0	58.3
	72,500		55,000	32,500	27.5	57.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
65,000	0.77	26.0	48.3
60,000	2.57	30.0	51.0
45,000	90.	32.0	64.8
40,000	360.	30.0	62.5
37,000	782.	24.0	43.7

Vickers Hardness: As received - 296
After 782 hours at 1200° F - 317

Alloy 4273 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	64,000
10	55,500
100	45,000
1000	36,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty as a small induction heat.
No information on forgeability of commercial heats.

MACHINABILITY Metal turned and threaded without difficulty.

NACA

ALLOY 4480

MANUFACTURER Crucible Steel Company of America

COMPOSITION 0.65% C, 0.44% Si, 4.24% Mn, 17.47% Cr, 4.05% Ni,
3.03% Mo

TREATMENT 30 pound induction furnace ingot. Forged 1950-1900° F
to 3/4 inch square. Cooled to 1300-1200° F and
finished with a few blows.

HARDNESS 302 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	145,000	63,750	89,700	42,500	12.0	13.0
	130,000	63,000	90,300	45,000	14.0	12.3
1200	76,750		49,600	20,000	25.0	38.2
	81,875		65,000	32,500	18.5	39.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
70,000	1.17	12.0	9.7
65,000	4.30	9.0	7.3
52,000	160.0	11.0	12.7
45,000	427.5	11.0	11.4
40,000	717.5	14.0	16.7
40,000	1117.0	9.0	9.7

Vickers Hardness: As received - 338
After 1117 hours at 1200° F - 390

Alloy 4480 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	70,000
10	62,000
100	56,000
1000	40,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty as a small induction heat.
No information on forgeability of commercial heats.

MACHINABILITY Metal turned and threaded without difficulty.

NACA

ALLOY 4481

MANUFACTURER Crucible Steel Company of America

COMPOSITION 0.89% C, 0.44% Si, 4.21% Mn, 17.65% Cr, 4.05% Ni,
2.95% MoTREATMENT 30 pound induction furnace ingot. Forged 1950-1900° F
to 3/4 inch square. Cooled to 1300-1200° F and
finished with a few blows.

HARDNESS 331 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	159,000	69,500	104,500	47,500	9.5	9.3
	135,000	69,000	90,300	45,000	4.5	5.0
1200	86,000		55,000	12,500	18.0	19.2
	79,125		58,000	12,500	21.0	32.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
70,000	0.82	14.0	9.1
65,000	2.63	25.0	34.5
50,000	32.5	32.0	39.9
43,000	301.0	14.0	26.2
43,000	228.5	29.0	42.8
38,000	495.0	24.0	43.2

Vickers Hardness: As received - 360
After 495 hours at 1200° F - 399

Alloy 4481 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	70,000
10	56,000
100	45,500
1000	36,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty as a small induction heat.
No information on forgeability of commercial heats.

MACHINABILITY Metal turned and threaded without difficulty.

NACA

ALLOY 4275

MANUFACTURER Crucible Steel Company of America

COMPOSITION 1.08% C, 0.49% Si, 4.04% Mn, 18.36% Cr, 4.05% Ni,
3.00% Mo

TREATMENT 30 pound induction furnace ingot. Forged 1950-1900° F
to 3/4 inch square. Cooled to 1300-1200° F and
finished with a few blows.

HARDNESS 326 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	154,000	60,000	94,650	50,000	7.5	7.0
	153,000	67,500	97,500	47,500	6.0	5.8
1200	90,000		65,000	45,000	15.0	17.3
	88,000		63,125	40,000	17.5	19.9

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
80,000	0.43	15.0	16.6
72,000	1.95	10.0	12.1
52,000	138.0	14.0	20.2
45,000	641.0	23.0	24.5
42,000	852.0	10.0	22.2

Vickers Harness: As received - 344
After 852 hours at 1200° F - 421

Alloy 4275 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	76,000
10	64,000
100	54,000
1000	42,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty as a small induction heat.
No information on forgeability of commercial heats.

MACHINABILITY Metal turned and threaded with difficulty.

NACA

ALLOY 234-A-5

MANUFACTURER Crucible Steel Company of America

COMPOSITION 0.38% C, 0.30% Si, 4.17% Mn, 18.52% Cr, 4.55% Ni,
1.35% Mo, 1.34% W, 0.57% Cb

TREATMENT 150 pound induction heat, hammered, finishing "cold"
at about 1200° F and stress relieved for one hour at
1200° F

HARDNESS 292 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	151,000	87,500	106,000	62,500	13.2	13.4
	155,500	81,800	104,700	55,000	22.5	31.1
1200	78,000		65,000	30,000	20.0	43.2
	79,500		67,500	32,500	19.5	44.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
68,000	0.34	22.0	49.2
62,000	2.96	18.0	56.9
55,000	54.0	26.0	60.0
50,000	83.0	27.0	60.9
46,000	231.5	16.0	46.5
45,000	468.0	18.0	41.8
40,000	535.0	12.0	39.0

Vickers Hardness: As received - 318
After 535 hours at 1200° F - 315

Alloy 234-A-5 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	65,000
10	58,000
100	50,000
1000	39,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Good.

MACHINABILITY Excellent.

NACA

ALLOY 4237

MANUFACTURER Crucible Steel Company of America

COMPOSITION 0.59% C, 1.44% Mn, 26.37% Cr, 30.62% Ni, 2.64% Ti

TREATMENT 30 pound induction furnace ingot. Forged 1950-1900° F to 3/4 inch square. Cooled to 1300-1200° F and finished with a few blows.

HARDNESS 249 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	123,250	76,875	98,125	62,500	14.5	34.7
	126,750	77,200	102,000	62,500	18.0	36.3
1200	99,500		84,375	32,500	14.0	19.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
88,000	0.13	14.0	23.5
78,000	0.28	15.0	31.3
68,000	3.42	15.0	33.4
50,000	51.5	7.0	12.0
42,000	91.0	4.0	12.0
40,000	136.0	6.0	7.8
35,000	819.0	6.0	8.5

Vickers Hardness: As received - 267
After 819 hours at 1200° F - 353

Alloy 4237 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	74,000
10	60,000
100	45,000
1000	34,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty as a small induction heat.
No information on forgeability of commercial heats.

MACHINABILITY Metal turned and threaded without difficulty.

NACA

ALLOY Rezistal VR

MANUFACTURER Crucible Steel Company of America

COMPOSITION 0.43% C, 0.82% Si, 0.85% Mn, 23.24% Cr, 4.79% Ni, 2.70% Mo

TREATMENT Melted in a commercial electric arc furnace, 7-inch square ingot. Hammer cogged at about 1900 to 2000° F to a 2¹/₄-inch square billet with two or three reheatings. Then rolled at about 1900 to 2000° F to a 1-inch round bar. Heated to 1400° F for 16 hours.

HARDNESS 332-377 Brinell.

TENSILE PROPERTIES*

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	170,000	73,500	105,600	57,500	0.5	1.0
	164,000	65,000	108,500	37,500	0.5	1.0
1200	74,000		41,000	15,000	17.5	24.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
65,000	0.30	20.0	16.7
52,000	1.88	34.0	39.8
30,000	56.0	51.0	45.7
25,000	87.0	57.0	51.4
20,000	193.	29.0	38.0

Vickers Hardness: As received - 436
After 193 hours at 1200° F - 448

Alloy Rezistal VR continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	56,000
10	43,000
100	24,500
1000	12,200

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY About equal to AISI Type 316.

MACHINABILITY Commercially machinable.

*Short-time tensile tests were made using an alloy of the following analysis: 0.45% C, 0.82% Mn, 23.38% Cr, 4.78% Ni, and 2.89% Mo. The method of treatment was the same as given. Hardness value - 403 to 397 Brinell.

NACA

ALLOY L2-T1*

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.12% C, 0.50% Si, 0.60% Mn, 18.0% Cr, 8.0% Ni, 2.0% Cb

TREATMENT Melted in induction furnace; 20 pound heat, $2\frac{1}{2}$ -inch square ingot. Pressed or forged to 1-inch square bar at 2050° F. Quenched in water from 2100° F.

HARDNESS 191 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	100,875	28,000	37,500	15,000	46.0	62.5
	98,750	25,000	36,000	15,000	43.0	62.9
1200	53,375		23,000	7,500	29.5	39.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
52,000	1.13	22.0	30.3
50,000	3.70	2.0	1.7
42,000	43.0	2.0	7.3
35,000	127.	4.0	12.1
30,000	493.	6.0	6.2

Vickers Hardness: As received - 191
After 493 hours at 1200° F - 200

Alloy L2-T1 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	52,000
10	48,000
100	37,000
1000	27,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Good

MACHINABILITY Good

*Alloys L2-T1, L2-T2, and L2-T3 are from the same heat and differ only in the processing following hot work.

NACA

ALLOY L2-T2*

MANUFACTURER Carnogie-Illinois Steel Corporation

COMPOSITION 0.12% C, 0.50% Si, 0.60% Mn, 18.0% Cr, 8.0% Ni, 2.0% Cb

TREATMENT Melted in induction furnace; 20 pound heat, $2\frac{1}{2}$ -inch square ingot. Pressed or forged to 1-inch square bar at 2050° F. Quenched into water at 2100° F. Area reduced 5% in one pass through rolling mill at 1200° F.

HARDNESS 199 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	101,250	49,000	65,000	37,500	40.5	60.3
	105,750	49,750	63,500	32,500	43.0	65.1
1200	58,000		50,000	32,000	16.0	33.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
56,500	1.07	8.0	21.2
55,000	2.9	5.0	12.1
45,000	54.0	1.0	2.5
35,000	75.5	2.0	12.1
33,000	149.5	2.0	3.8
30,000	386.	2.0	0.0

Vickers Hardness: As received - 204
After 386 hours at 1200° F - 239

Alloy L2-T2 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	56,000
10	52,000
100	37,000
1000	26,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Good

MACHINABILITY Good

*Alloys L2-T1, L2-T2, and L2-T3 are from the same heat and differ only in the processing following hot work.

NACA

ALLOY L2-T3*

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.12% C, 0.50% Si, 0.60% Mn, 18.0% Cr, 8.0% Ni, 2.0% Cb

TREATMENT Melted in induction furnace; 20 pound heat, $2\frac{1}{2}$ -inch square ingot. Pressed or forged to 1-inch square bar at 2050° F. Quenched into water at 2100° F. Area reduced 10 to 12% in one pass through rolling mill at 1200° F.

HARDNESS 223 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	107,750	55,500	76,500	30,000	37.5	57.3
	110,500	58,750	77,500	40,000	40.0	63.4
1200	62,000		57,000	42,500	12.0	31.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
60,000	1.81	2.0	12.1
58,000	3.61	2.0	4.2
45,000	29.0	2.0	6.1
35,000	92.5	1.0	1.0
30,000	391.	1.0	3.7

Vickers Hardness: As received - 257
After 391 hours at 1200° F - 245

Alloy L2-T3 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	62,000
10	52,000
100	37,000
1000	26,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Good

MACHINABILITY Good

*Alloys L2-T1, L2-T2, and L2-T3 are from the same heat and vary only in the processing following hot work.

NACA

ALLOY L3-T1*

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.12% C, 2.0% Si, 0.60% Mn, 18.0% Cr, 8.0% Ni, 2.0% Cb

TREATMENT Melted in induction furnace; 20 pound heat, $2\frac{1}{2}$ -inch square ingot. Pressed or forged at 2050° F to 1-inch square bar. Quenched into water from 2100° F.

HARDNESS 204 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	116,125	33,750	46,500	22,500	44.0	56.2
	113,875	33,750	46,250	20,000	44.0	55.7
1200	57,500		30,000	10,000	38.0	50.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
53,000	1.20	18.0	27.2
50,000	4.51	16.0	20.7
42,000	43.5	6.0	6.1
32,000	160.	6.0	9.1
28,000	577.	4.0	11.5

Vickers Hardness: As received - 210
After 577 hours at 1200° F - 215

Alloy L3-T1 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	54,000
10	48,000
100	36,000
1000	25,700

COMMENTS SUPPLIED BY THE MANUFACTURER

FORMABILITY Good

MACHINABILITY Good

*Alloys L3-T1, L3-T2, and L3-T3 are from the same heat and differ only in the processing following hot work.

NACA

ALLOY L3-T2*

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.12% C, 2.0% Si, 0.60% Mn, 18.0% Cr, 8.0% Ni, 2.0% Cb

TREATMENT Melted in induction furnace; 20 pound heat, $2\frac{1}{2}$ -inch square ingot. Pressed or forged to 1-inch square bar at 2050° F. Quenched into water at 2100° F. Area reduced 5% in one pass through rolling mill at 1200° F.

HARDNESS 228 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	118,750	58,500	75,500	40,000	40.0	52.2
	121,250	54,000	72,500	40,000	40.0	53.5
1200	59,875		48,750	25,000	26.0	45.2

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
58,000	1.55	11.0	24.5
56,000	4.07	6.0	17.2
45,000	34.5	4.0	6.2
35,000	176.	1.0	2.0

Vickers Hardness: As received - 223
After 176 hours at 1200° F - 261

Alloy L3-T2 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	60,000
10	55,000
100	38,000
1000	27,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Good

MACHINABILITY Good

*Alloys L3-T1, L3-T2, and L3-T3 are from the same heat and differ only in the treatment following hot work.

NACA

ALLOY L3-T3*

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.12% C, 2.0% Si, 0.60% Mn, 18.0% Cr, 8.0% Ni, 2.0% Cb

TREATMENT Melted in induction furnace; 20 pound heat, $2\frac{1}{2}$ -inch square ingot. Pressed or forged to 1-inch square bar at 2050° F. Quenched into water at 2100° F. Area reduced 10 to 12% in one pass through rolling mill at 1200° F.

HARDNESS 265 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	122,750	70,500	88,750	42,500	38.0	53.0
	127,000	72,500	93,000	42,500	38.0	55.2
1200	67,000		63,000	37,500	20.0	42.2

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
65,000	1.10	18.0	32.0
63,000	2.38	7.0	19.5
48,000	50.25	1.0	2.4
38,000	122.5	3.0	1.0
32,000	538.	2.0	3.0

Vickers Hardness: As received - 285
After 538 hours at 1200° F - 273

Alloy L3-T3 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	66,000
10	59,000
100	41,500
1000	28,700

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Good

MACHINABILITY Good

*Alloys L3-T1, L3-T2, and L3-T3 are from the same heat and differ only in the treatment following hot work.

NACA

ALLOY 2605

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.15% C, 0.25% Si, 0.85% Mn, 13.00% Cr, 32.00% Ni,
3.00% Mo, 2.00% W

TREATMENT Melted in induction furnace; 30 pound heat. Ingot pressed
or forged to 1-inch square bar. Initial forging done at
2000 to 2100° F. Final working done at relatively low
temperature in order to approach the kind of "cold work"
desired. No further heat treatment.

HARDNESS 238 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	120,000	68,000	82,000	52,500	30.5	51.9
	123,750	72,000	88,750	57,500	27.0	51.7
1200	87,500		58,750	35,000	19.5	24.3
	81,750		52,500	32,500	15.0	16.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
75,000	0.78	15.0	23.9
70,000	1.20	14.0	16.8
50,000	39.0	8.0	12.1
40,000	146.	6.0	9.7

Vickers Hardness: As received - 247
After 146 hours at 1200° F - 233

Alloy 2605 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	73,500
10	62,000
100	43,000
1000	28,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORMABILITY Fair

MACHINABILITY Fair

NACA

ALLOY 2606

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.15% C, 0.25% Si, 0.85% Mn, 13.00% Cr, 32.00% Ni,
2.50% Co, 3.00% Mo, 2.00% W

TREATMENT Melted in induction furnace; 30 pound heat. Ingot pressed or forged to 1-inch square bar. Initial forging done at 2000 to 2100° F. Final working done at relatively low temperature in order to approach the kind of "cold work" desired. No further heat treatment.

HARDNESS 201 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	115,000	57,500	71,000	50,000	31.0	53.6
	112,500	61,000	70,000	55,000	36.0	58.3
1200	77,000		41,250	25,000	15.0	17.5
	76,750		48,500	27,500	11.0	18.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
73,000	1.45	10.0	9.6
68,000	4.58	10.0	19.5
50,000	38.0	10.0	9.1
38,000	211.	7.0	13.7

Vickers Hardness: As received - 212
After 211 hours at 1200° F - 224

Alloy 2606 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	75,500
10	62,000
100	42,500
1000	29,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Fair

MACHINABILITY Fair

NACA

ALLOY 2607

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.30% C, 0.25% Si, 0.85% Mn, 13.00% Cr, 32.00% Ni, 3.00% Mo, 2.00% W

TREATMENT Melted in induction furnace; 30 pound heat. Ingot pressed or forged to 1-inch square bar. Initial forging done at 2000 to 2100° F. Final working done at relatively low temperature in order to approach the kind of "cold work" desired. No further heat treatment.

HARDNESS 231 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional Limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	113,250	40,500	62,500	25,000	28.0	45.2
	119,750	53,500	78,000	40,000	28.0	44.0
1200	81,500		47,500	30,000	14.0	17.3
	85,500		56,500	32,500	14.0	14.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
75,000	0.13	24.0	36.0
65,000	7.73	2.0	6.1
50,000	22.4	13.0	16.1
33,000	666.	6.0	7.3

Vickers Hardness: As received - 249
After 666 hours at 1200° F - 227

Alloy 2607 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	89,500
10	60,000
100	43,000
1000	31,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Fair

MACHINABILITY Fair

NACA

ALLOY 2608

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.30% C, 0.25% Si, 0.85% Mn, 13.00% Cr, 32.00% Ni,
2.50% Co, 3.00% Mo, 2.00% WTREATMENT Melted in induction furnace; 30 pound heat. Ingot
pressed or forged to 1-inch square bar. Initial
forging done at 2000 to 2100° F. Final working done
at relatively low temperature in order to approach
the kind of "cold work" desired. No further heat
treatment.

HARDNESS 219 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	122,250	66,000	83,000	52,500	26.0	40.1
	117,500	60,000	76,500	45,000	24.0	39.8
1200	86,375		63,500	35,000	11.0	13.1
	88,250		61,500	37,500	12.0	16.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
78,000	0.12	23.0	21.2
70,000	0.95	15.0	34.4
66,000	2.80	8.0	16.7
50,000	36.75	14.0	23.4
33,000	1403.	6.0	9.1

Vickers Hardness: As received - 223

After 1403 hours at 1200° F - 240

Alloy 2608 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	70,000
10	53,000
100	44,600
1000	34,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Fair.

MACHINABILITY Fair.

NACA

ALLOY L4

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.11% C, 0.26% Si, 0.67% Mn, 12.56% Cr, 32.53% Ni,
10.95% Co, 3.70% Mo, 2.14% W, 0.067% N₂TREATMENT Melted in an induction furnace, 20 pound ingot. Hot
forged to about 1-inch square bar. Heated 1 hour at
2050° F and quenched in water. Reheated to 1200° F
and reduced in area approximately 10% by rolling.

HARDNESS 232 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	115,500	66,800	85,500	42,500	28.5	55.2
	115,750	72,200	89,000	40,000	27.0	57.3
1200	85,000		67,500	20,000	9.0	16.7
	85,250		65,300	27,500	12.0	17.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
76,000	0.95	2.0	15.1
68,000	1.60	1.0	7.3
47,000	22.0	1.0	9.7
44,000	100.0	3.0	2.3
35,000	493.0	1.0	1.0

Vickers Hardness: As received - 247
After 493 hours at 1200° F - 252

Alloy L4 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data.)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	74,000
10	56,000
100	42,000
1000	32,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Good.

MACHINABILITY Good.

NACA

ALLOY L7

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.36% C, 0.44% Si, 0.47% Mn, 32.40% Ni, 12.42% Cr,
3.82% Mo, 2.31% W, 9.55% Co, .05% N₂TREATMENT Melted in an induction furnace, 20 pound ingot.
Hot forged to about 1-inch square bar. Heated
to 2050° F for 1 hour and water quenched. Re-
heated to 1200° F and reduced in area 10% by
rolling. Air cooled.

HARDNESS 307 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional Limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	144,250	107,000	127,000	95,000	17.5	30.6
	151,000	106,300	130,300	90,000	8.5	21.6
1200	89,250		77,000	57,500	4.5	6.3

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
80,000	.93	1.0	2.4
72,000	3.00	0.	0.
50,000	179.5	4.0	3.7
45,000	284.0	1.0	1.2
40,000	265.5	4.0	4.8

Vickers Hardness: As received - 343
After 565.5 hours at 1200° F - 274

Alloy L7 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	80,000
10	65,000
100	52,000
1000	36,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Fair.

MACHINABILITY Good.

NACA

ALLOY LL-T1*

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.30% C, 0.60% Si, 0.50% Mn, 13.0% Cr, 33.0% Ni, 10.5% Co, 3.5% Mo, 2.1% W

TREATMENT Melted in induction furnace; 20 pound heat, $2\frac{1}{2}$ -inch square ingot. Pressed or forged to 1-inch square bar at 2050° F. Quenched into water from 2100° F.

HARDNESS 197 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	113,625	37,500	54,500	20,000	36.0	70.1
	114,625	45,500	54,500	37,500	35.0	52.8
1200	82,500		42,500		12.0	15.2
	86,500		42,500	20,000	13.0	4.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
70,000	0.97	6.0	10.8
65,000	4.10	---	12.1
50,000	28.5	16.0	22.7
40,000	135.	11.0	8.5
35,000	589.	11.0	14.5

Vickers Hardness: As received - 261
After 589 hours at 1200° F - 234

Alloy L1-T1 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	70,000
10	58,000
100	43,000
1000	32,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Fair.

MACHINABILITY Fair.

*Alloys L1-T1, L1-T2, and L1-T3 are from the same heat and differ only in the processing following hot work.

NACA

ALLOY L1-T2*

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.30% C, 0.60% Si, 0.50% Mn, 13.0% Cr, 33.0% Ni,
10.5% Co, 3.5% Mo, 2.1% W

TREATMENT Melted in induction furnace; 20 pound heat, $2\frac{1}{2}$ -inch square ingot. Pressed or forged to 1-inch square bar at 2050° F. Quenched into water from 2100° F. Area reduced 5% in one pass through rolling mill at 1200° F.

HARDNESS 251 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	124,250	73,000	91,000	55,000	28.0	31.5
	129,875	82,000	102,000	60,000	22.5	38.5
1200	95,125		82,500	45,000	5.0	6.6

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
72,000	1.42	1.0	9.7
65,000	5.03	1.0	3.8
50,000	84.0	3.0	4.3
40,000	344.	6.0	6.7

Vickers Hardness: As received - 262
After 344 hours at 1200° F - 251

Alloy L1-T2 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	74,000
10	62,000
100	48,500
1000	33,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Fair.

MACHINABILITY Fair.

*Alloys L1-T1, L1-T2, and L1-T3 are from the same heat and differ only in the processing following hot work.

NACA

ALLOY L1-T3*

MANUFACTURER Carnegie-Illinois Steel Corporation

COMPOSITION 0.30% C, 0.60% Si, 0.50% Mn, 13.0% Cr, 33.0% Ni,
10.5% Co, 3.5% Mo, 2.1% W

TREATMENT Melted in induction furnace; 20 pound heat, $2\frac{1}{2}$ -inch square ingot. Pressed or forged to 1-inch square bar at 2050° F. Quenched into water from 2100° F. Area reduced 10 to 12% in one pass through rolling mill at 1200° F.

HARDNESS 291 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	143,250	102,000	125,000	70,000	17.0	32.1
	142,750	102,500	127,500	72,500	17.5	38.4
1200	101,875		90,625	55,000	5.5	9.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
80,000	0.37	3.0	4.8
75,000	0.85	3.0	2.3
68,000	1.57	2.0	4.8
50,000	110.5	4.0	3.7
40,000	538.	4.0	3.7

Vickers Hardness: As received - 315
After 538 hours at 1200° F - 277

Alloy L1-T3 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	74,000
10	62,000
100	50,000
1000	37,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Fair.

MACHINABILITY Fair.

*Alloys L1-T1, L1-T2, and L1-T3 are from the same heat and differ only in the processing following hot work.

NACA

ALLOY Age Hardenable Inconel

MANUFACTURER International Nickel Company, Inc.

COMPOSITION 0.03% C, 0.52% Si, 0.53% Mn, 0.10% Cu, 74.82% Ni, 14.40% Cr, 0.63% Al, 2.77% Ti, 6.17% Fe, .007% S.

TREATMENT Hot-rolled 7/8-inch round bar. Heated 2 hours at 1950° F and water quenched. Aged 16 hours at 1300° F.

HARDNESS 308 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	178,500	107,500	119,000	70,000	28.5	41.3
	177,500	101,000	118,300	70,000	27.5	38.9
1200	123,500		108,800	50,000	6.0	11.6
	130,500		107,500	47,500	7.5	10.3

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
110,000	.42	5.0	12.1
90,000	4.85	4.0	10.0
60,000	88.0	3.0	13.2
50,000	288.0	1.0	1.2
45,000	377.0	0.	1.2
44,000	490.5	2.0	0.

Vickers Hardness: As received - 330
After 490.5 hours at 1200° F - 358

Alloy Age Hardenable Inconel continued

STRESS-RUPTURE PROPERTIES AT 12000° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	103,000
10	84,000
100	59,000
1000	38,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY

Billets to be forged should be heated rapidly to 2050 to 2250° F and not allowed to "soak". The metal should be charged into a furnace at temperature and should not be held longer than 1/2 hour after reaching temperature. The heating furnace atmosphere should be slightly reducing. An excess of 2% C is recommended.

The best heating temperature for forging is 2225 ± 25° F and working must be discontinued when the piece cools to 1900-2000° F range. The metal must then be reheated for further forging.

Provision must be made to cool the metal from the hot-working temperature to a black heat in less than three minutes.

The 0.02% offset yield strength at room temperature can be increased by as much as 50% by heating to 1200-1400° F and reducing 15% under a hammer.

Annealed stock has been cold formed at room temperature without difficulty in standard dies and presses.

MACHINABILITY

Machine with high speed or carbide tools at reasonable speeds such as must be used on any metal of similar hardness and yield strength.

NACA

ALLOY Nimonic 80

MANUFACTURER International Nickel Company, Inc.

COMPOSITION 0.04% C, 0.49% Si, 0.56% Mn, 0.04% Cu, 74.23% Ni,
21.18% Cr, 0.63% Al, 2.44% Ti, 0.38% Fe, 0.005% S.TREATMENT Hot-rolled 1-inch round bar. Heated 2 hours at
1950° F and water quenched. Aged 16 hours at
1300° F.

HARDNESS 260 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.2%	0.2%			
80	149,500	82,300	89,500	75,000	39.5	39.8
	153,000	80,200	83,800	75,000	36.5	33.6
1200	97,500		77,000	30,000	14.5	20.8
	93,000		76,800	30,000	9.0	15.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
82,000	0.22	1.0	9.7
73,000	11.03	8.0	12.1
60,000	68.0	1.0	1.8
50,000	297.5	2.0	5.5
44,000	50.0	1.0	0
44,000	376.0	2.0	1.2
42,000	87.5	3.0	2.4
42,000	252.5	2.0	1.2

Vickers Hardness: As received - 280
After 252.5 hours at 1200° F - 308

Alloy Nimonic 80 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	76,000
10	61,000
100	49,000
1000	39,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY

Billets to be forged should be heated rapidly to 2050 to 2250° F and not allowed to "soak". The metal should be charged into a furnace at temperature and should not be held longer than 1/2 hour after reaching temperature. The heating furnace atmosphere should be slightly reducing. An excess of 2% C is recommended.

The best heating temperature for forging is 2225 ±25° F and working must be discontinued when the piece cools to 1900-2000° F range. The metal must then be reheated for further forging.

Provision must be made to cool the metal from the hot-working temperature to a black heat in less than three minutes.

The 0.02% offset yield strength at room temperature can be increased by as much as 50% by heating to 1200-1400° F and reducing 15% under a hammer.

Annealed stock has been cold formed at room temperature without difficulty in standard dies and presses.

MACHINABILITY

Machine with high speed or carbide tools at reasonable speeds such as must be used on any metal of similar hardness and yield strength.

NACA

ALLOY 17W - Annealed* (B7182)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.49% C, 0.61% Si, 0.61% Mn, 13.12% Cr, 19.11% Ni,
0.58% Mo, 2.38% W, 0.030% N₂

TREATMENT Melted in an electric arc furnace, 12,000 pound heat.
Ingots hammer cogged. Rolled at 2045/1800° F to 3/4-
inch square bar. Then air cooled from 2150° F.

HARDNESS 192 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.00%	0.2%			
80	109,000	34,000	48,200	25,000	39.0	44.6
	109,625	36,500	48,500	27,500	39.0	36.9
1200	70,000		28,000	15,000	15.0	16.7
	68,500		28,000	15,000	19.0	14.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
55,000	0.50	6.0	12.2
48,000	6.2	--	6.1
35,000	85.0	2.0	1.3
32,000	641.	2.0	5.1
30,000	741.	2.0	2.5

Vickers Hardness: As received - 206
After 741 hours at 1200° F - 248

Alloy 17W - Annealed continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	55,000
10	44,000
100	36,000
1000	29,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Used as a standard for comparison with other Universal-Cyclops alloys. More difficult than "18-8" grades.

MACHINABILITY Used as a standard for comparison with other Universal-Cyclops alloys. More difficult than "18-8" grades.

*Alloys 17W, 17WH, and 17WA are from the same heat and differ only in processing.

NACA

ALLOY 17W - Hot Rolled* (B 7182)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.49% C, 0.61% Si, 0.61% Mn, 13.12% Cr, 19.11% Ni,
0.58% Mo, 2.36% W

TREATMENT Melted in electric arc furnace, 12,000 pound heat.
Ingots hammer cogged. Rolled at 2045/1800° F to 3/4-
inch square bar. Stress relieved by soaking thru at
1200° F. Air cooled.

HARDNESS 208 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.) 0.02% 0.2%		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
80	110,000	43,500	57,500	27,500	31.0	40.8
	108,000	36,250	56,250	20,000	33.0	40.8
1200	63,250		33,500	10,000	32.0	35.7
	64,750		33,500	10,000	31.5	32.2

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
58,000	0.63	34.0	32.0
53,000	1.92	24.0	26.7
40,000	11.0	24.0	22.8
35,000	41.0	25.0	30.9
30,000	165.	24.0	26.7
26,500	170.	22.0	28.7
25,000	205.	26.0	34.5

Vickers Hardness: As received - 219
After 205 hours at 1200° F - 200

Alloy 17W Hot Rolled continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	56,000
10	42,500
100	30,000
1000	21,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Used as a standard for comparison with other Universal-Cyclops alloys. More difficult than "18-8" grades.

MACHINABILITY Used as a standard for comparison with other Universal-Cyclops alloys. More difficult than "18-8" grades.

*Alloys 17W, 17WH, and 17WA are from the same heat and differ only in processing.

NACA

ALLOY 17W - "Cold" Worked* (Rolled at 1200° F)(B7182)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.42% C, 0.61% Si, 0.61% Mn, 13.12% Cr, 19.11% Ni,
0.58% Mo, 2.36% W, 0.030% N₂

TREATMENT Melted in electric arc furnace, 12,000 pound heat.
Ingots hammer cogged. Rolled at 2045/1800° F to 7/8-
inch square bar. Rolled at 1200° F to 20.8% reduction
in area. Stress relieved by soaking thru at 1200° F.
Air cooled.

HARDNESS 335 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	164,000	102,000	151,500	62,500	14.0	23.7
	163,750	121,000	154,000	65,000	13.0	23.7
1200	99,000		72,000	37,500	6.0	24.8
	100,375		76,000	30,000	6.0	9.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
84,000	0.43	8.0	7.3
74,000	1.18	9.0	10.9
45,000	50.0	12.0	13.3
38,000	70.5	10.0	6.1
37,000	129.0	10.0	17.8
31,000	176.5	8.0	6.2
25,000	456.	9.0	9.1

Vickers Hardness: As received - 323
After 456 hours at 1200° F - 250

Alloy 17W - "Cold" Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	76,000
10	57,000
100	37,000
1000	20,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Used as a standard for comparison with other Universal-Cyclops alloys. More difficult than "18-8" grades.

MACHINABILITY Used as a standard for comparison with other Universal-Cyclops alloys. More difficult than "18-8" grades.

*Alloys 17W, 17WH, and 17WA are from the same heat and differ only in processing.

NACA

ALLOY 17W-Hot Worked (Rolled at 1700° F.)(B7436)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.48% C, 0.47% Si, 0.58% Mn, 13.38% Cr, 19.10% Ni, 0.66% Mo, 2.55% W.

TREATMENT Melted in electric arc furnace, 12,000 pound heat. Hammer forged. Rolled at 2045/1800° F to 7/8-inch square bar. Heated 1 hour at 2100° F and air cooled. Reheated to 1700° F and reduced in area 23.74% by rolling. Stress relieved by heating through at 1200° F and air cooled.

HARDNESS 228 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	114,500	74,000	88,000	60,000	32.0	55.0
	115,000	75,000	88,000	62,500	32.5	54.7
1200	73,750		65,000	35,000	10.0	17.7
	72,250		58,000	32,500	14.0	21.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
63,000	0.67	10.0	15.6
55,000	3.83	4.0	6.2
45,000	98.5	3.0	8.6
40,000	249.0	6.0	8.6
35,000	550.0	3.0	1.0

Vickers Hardness: As received - 212
After 550 hours at 1200° F - 243

Alloy 17W-Hot Worked (Rolled at 1700° F.)(B7436) continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	62,000
10	52,000
100	45,000
1000	32,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Used as standard for comparison with other
Universal-Cyclops alloys. More difficult than
"18-8" grades.

MACHINABILITY Used as standard for comparison with other
Universal-Cyclops alloys. More difficult than
"18-8" grades.

NACA

ALLOY 17W-"Cold" Worked (R1644)(Rolled at 1200° F.)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.49% C, 0.75% Si, 0.77% Mn, 13.41% Cr, 20.26% Ni,
0.84% Mo, 2.62% W, 0.059% N₂

TREATMENT Melted in an induction furnace; 33 pound ingot.
Hammer forged at 2050/1785° F. Rolled at 2090/
1900° F to 7/8-inch square bar. Heated 1 hour at
2100° F and air cooled. Reheated to 1200° F and
reduced in area 17.80% by rolling. Stress relieved
by heating through at 1200° F and air cooled.

HARDNESS 313 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	158,500	112,500	138,500	90,000	15.5	30.2
	149,500	103,000	130,000	82,500	13.5	28.2
1200	94,000		81,250	50,000	10.0	18.8
	98,750		86,250	50,000	10.0	18.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
82,000	0.70	8.0	14.5
75,000	1.83	5.0	6.2
50,000	38.0	10.0	12.1
40,000	105.0	14.0	16.7
37,000	132.0	4.0	2.6
34,000	204.0	6.0	7.3

Vickers Hardness: As received - 315
After 204 hours at 1200° F - 252

Alloy 17W-"Cold" Worked (R1644)(Rolled at 1200° F) continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	79,500
10	63,500
100	40,000
1000	23,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Used as standard for comparison with other
Universal-Cyclops alloys. More difficult than
"18-8" grades.

MACHINABILITY Used as standard for comparison with other
Universal-Cyclops alloys. More difficult than
"18-8" grades.

NACA

ALLOY 17W-NM (R1658)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.48% C, 0.68% Si, 0.48% Mn, 20.22% Cr, 20.21% Ni,
0.67% Mo, 2.50% W, 0.16% N₂.

TREATMENT Melted in an induction furnace; 33 pound ingot. Hot
forged to 7/8-inch squares. Heated 1 hour at 2100° F
and air cooled. Reheated to 1200° F and reduced in
area 20% by rolling. Stress relieved by heating
through at 1200° F and air cooled.

HARDNESS 323 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.) 0.02% 0.2%	Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
80	159,000*			8.0	18.9
	153,500	101,000	132,500	8.5	11.1
1200	102,000*			10.0	29.8

*Tensile tests on 0.160 inch diameter bars.

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
90,000	.67	6.0	17.2
83,000	1.55	4.0	2.5
58,000	40.5	5.0	3.6
50,000	66.0	2.0	3.6
45,000	70.5	5.0	7.3
40,000	180.5	6.0	7.3

Vickers Hardness: As received - 330
After 180.5 hours at 1200° F - 284

Alloy 17W-NM continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	86,500
10	70,500
100	46,000
1000	28,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY More difficult than 17W.

MACHINABILITY About the same as 17W.

NACA

ALLOY 17 W-Cb (E735)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.47% C, 0.84% Si, 0.61% Mn, 12.59% Cr, 19.06% Ni,
0.63% Mo, 2.38% W, 1.08% Cb

TREATMENT Melted in electric arc furnace, 2000 pound heat.
Rolled at 2065/1850° F to 7/8-inch square bar, then
rolled at 1200° F to 20.8% reduction in area. Stress
relieved by soaking thru at 1200° F. Air cooled.

HARDNESS 335 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	155,000	123,000	146,000	90,000	13.5	32.7
	156,500	127,000	148,500	105,000	15.0	31.7
1200	102,500		91,000	22,500	7.0	21.4
	105,500		91,500	30,000	9.5	18.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
88,000	1.28	2.0	6.2
82,000	2.52	2.0	6.2
50,000	69.5	2.0	1.7
37,000	218.	3.0	2.4
30,000	504.	4.0	2.4

Vickers Hardness: As received - 307
After 504 hours at 1200° F - 261

Alloy 17 W-Cb continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	84,000
10	69,000
100	45,000
1000	25,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forges better than 17W.

MACHINABILITY About the same as 17W.

NACA

ALLOY Low Carbon 17W - Annealed* (A9476)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.28% C, 0.72% Si, 0.72% Mn, 12.56% Cr, 19.35% Ni,
0.62% Mo, 2.12% W.

TREATMENT Melted in an electric arc furnace; 12,000 pound
heat. Hammer forged. Rolled at 2090/1900° F to
3/4-inch square bar. Heated 1 hour at 2100° F
and air cooled.

HARDNESS 184 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	101,500	40,000	48,750	32,500	43.0	57.5
	101,750	40,000	48,750	32,500	42.0	56.2
1200	76,250		31,000	17,500	23.0	27.2
	72,500		28,500	17,500	27.0	27.2

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
66,000	0.33	17.0	24.5
56,000	2.37	12.0	20.6
45,000	91.0	12.0	18.9
40,000	276.0	10.0	21.2
36,000	686.0	13.0	12.3

Vickers Hardness: As received - 185
After 686 hours at 1200° F - 224

Alloy Low Carbon 17W - Annealed continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	60,000
10	54,000
100	44,000
1000	34,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat better than 17W

MACHINABILITY Somewhat better than 17W

*Alloys Low Carbon 17W - Annealed, Low Carbon 17W - Hot worked and Low Carbon 17W - "Cold" worked are from the same heat and differ only in processing.

NACA

ALLOY Low Carbon 17W - Hot Worked* (A9476)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.28% C, 0.72% Si, 0.72% Mn, 12.56% Cr, 19.35% Ni,
0.62% Mo, 2.12% W.

TREATMENT Melted in an electric arc furnace; 12,000 pound
heat. Hammer forged. Rolled at 2090/1900° F
to 7/8-inch square bar. Heated 1 hour at 2100° F
and air cooled. Reheated to 1700° F and reduced
in area 24.47% by rolling. Stress relieved by
heating through at 1200° F and air cooled.

HARDNESS 230 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	116,750	76,000	90,500	62,500	26.0	47.2
	116,500	76,000	90,500	62,500	25.5	47.5
1200	72,750		60,000	40,000	15.5	29.9
	77,250		62,000	37,500	17.0	29.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
70,000	1.42	9.0	10.8
65,000	5.20	7.0	20.7
54,000	44.0	12.0	22.3
46,000	135.0	9.0	25.6
40,000	507.0	7.0	4.3

Vickers Hardness: As received - 257
After 507 hours at 1200° F - 258

Alloy Low Carbon 17W - Hot Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	72,000
10	62,000
100	49,000
1000	37,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat better than 17W.

MACHINABILITY Somewhat better than 17W.

*Low Carbon 17W - Annealed, Low Carbon 17W - Hot worked, and Low Carbon 17W - "Cold" worked are from the same heat and differ only in processing.

NACA

ALLOY Low Carbon 17W - "Cold" Worked* (A9476)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.28% C, 0.72% Si, 0.72% Mn, 12.56% Cr, 19.35% Ni,
0.62% Mo, 2.12% W.

TREATMENT Melted in an electric arc furnace; 12,000 pound heat. Hammer forged. Rolled at 2090/1900° F to 7/8-inch square bar. Heated 1 hour at 2100° F and air cooled. Reheated to 1200° F and reduced in area 22.91% by rolling. Stress relieved by heating through at 1200° F and air cooled.

HARDNESS 291 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	139,500	108,500	125,500	92,500	20.0	43.1
	139,000	109,500	124,500	95,000	19.5	40.7
1200	90,500		82,500	50,000	10.0	18.8
	87,750		80,000	40,000	9.0	23.2

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
83,000	1.68	6.0	10.3
79,000	2.80	4.0	7.3
55,000	87.0	3.0	2.3
48,000	197.0	3.0	3.7
42,000	296.0	2.0	1.0
40,000	357.5	2.0	1.3

Vickers Hardness: As received - 262
After 357.5 hours at 1200° F - 286

Alloy Low Carbon 17W - "Cold" Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	85,000
10	75,000
100	55,000
1000	31,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat better than 17W.

MACHINABILITY Somewhat better than 17W.

*Low Carbon 17W - Annealed, Low Carbon 17W - Hot worked, and Low Carbon 17W - "Cold" worked are from the same heat and differ only in processing.

NACA

ALLOY 16-25-6 - Annealed (Timken Alloy)*

MANUFACTURER Ingot obtained from The Timken Roller Bearing Co., Steel and Tube Division, and fabricated by the Universal-Cyclops Steel Corporation

COMPOSITION 0.15% C, 0.84% Si, 1.14% Mn, 16.75% Cr, 25.26% Ni, 6.29% Mo, 0.01% P, 0.022% S, 0.175% Nb.

TREATMENT Melted in an electric arc furnace. Hammer forged at 2065/1300° F to 3/4-inch square bar. Heated 1 hour at 2100° F and air cooled.

HARDNESS 207 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	121,375	48,500	59,700	35,000	39.0	51.1
	118,375	45,200	56,300	35,000	40.0	51.3
1200	83,500		36,200	17,500	22.0	21.1
	81,750		35,700	20,000	21.0	19.6

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
75,000	0.62	18.0	17.3
67,000	2.67	10.0	16.7
50,000	89.0	13.0	11.4
44,000	199.0	17.0	28.2
35,000	990.0	11.0	21.6

Vickers Hardness: As received - 214
After 990 hours at 1200° F - 271

Alloy 16-25-6 - Annealed continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	72,000
10	61,000
100	49,000
1000	35,000

COMMENTS SUPPLIED BY THE MANUFACTURER

(Supplied by The Timken Roller Bearing Co., Steel and Tube Division)

FORGEABILITY As this material possesses excellent high-temperature strength, it will be found to be very hard under the hammer at the forging temperature. A maximum forging temperature of 2050° F is recommended. The material should not be soaked at temperatures above 2000° F, although soaking below this temperature is permissible and is advisable if large sections have to be produced.

MACHINABILITY This material may readily be machined. Its machinability is at least equal to that of the austenitic 18-8 steel.

*Alloys 16-25-6 - Annealed, 16-25-6 - Hot Worked, and 16-25-6 - "Cold" Worked are from the same billet and differ only in processing.

NACA

ALLOY 16-25-6 - How Worked (Timken Alloy)*

MANUFACTURER Ingot obtained from the Timken Roller Bearing Co., Steel and Tube Division, and fabricated by the Universal-Cyclops Steel Corporation

COMPOSITION 0.15% C, 0.84% Si, 1.14% Mn, 16.75% Cr, 25.26% Ni, 6.29% Mo, 0.175% N₂.

TREATMENT Melted in an electric arc furnace. Forged and rolled 2065/1650° F to 7/8-inch square bar. Heated 1 hour at 2100° F and air cooled. Re-heated to 1700° F and reduced in area 25.17% by rolling and air cooled. Stress relieved by heating through at 1200° F and air cooled.

HARDNESS 279 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	137,500	94,500	111,500	82,500	19.5	35.4
	138,000	95,000	111,000	80,000	18.5	30.8
1200	97,750		76,500	47,500	21.0	36.6
	93,250		76,000	45,000	20.5	36.1

STRESS-TUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
83,000	0.70	22.0	39.4
75,000	4.73	13.0	26.7
60,000	38.5	27.0	40.9
50,000	95.0	28.0	43.7
48,000	156.5	25.0	34.4
38,000	1257.5	18.0	24.0

Vickers Hardness: As received - 295
After 1257.5 hours at 1200° F - 290

Alloy 16-25-6 - Hot Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	82,000
10	69,000
100	52,000
1000	39,000

COMMENTS SUPPLIED BY THE MANUFACTURER
(Supplied by The Timken Roller Bearing Co., Steel and Tube Division)

FORCEABILITY As this material possesses excellent high-temperature strength, it will be found to be very hard under the hammer at the forging temperature. A maximum forging temperature of 2050° F is recommended. The material should not be soaked at temperatures above 2000° F, although soaking below this temperature is permissible and is advisable if large sections have to be produced.

MACHINABILITY This material may readily be machined. Its machinability is at least equal to that of austenitic 18-8 steel.

*Alloys 16-25-6 Annealed, 16-25-6 Hot Worked, and 16-25-6 "Cold" Worked are from the same ingot and differ only in processing.

NACA

ALLOY 16-25-6 - Cold Worked (Timken Alloy)*

MANUFACTURER Ingot obtained from The Timken Roller Bearing Co., Steel and Tube Division, and fabricated by the Universal-Cyclops Steel Corporation

COMPOSITION 0.15% C, 0.84% Si, 1.14% Mn, 16.75% Cr, 25.26% Ni, 6.23% Mo, 0.175% N₂.

TREATMENT Melted in an electric arc furnace. Forged and rolled 2065/1650° F to 7/8-inch square bar. Heated 1 hour at 2100° F and air cooled. Re-heated to 1200° F and reduced in area 22.53% by rolling. Air cooled. Stress relieved by heating through at 1200° F and air cooled.

HARDNESS 326 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.) 0.02% 0.2%		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
80	162,250	121,000	143,500	102,500	15.5	33.8
	161,750	117,000	143,500	92,500	16.0	34.1
1200	105,250		92,500	62,500	14.0	28.8
	107,500		94,000	60,000	13.0	27.9

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
96,000	0.95	7.0	15.6
90,000	1.70	6.0	22.3
65,000	35.0	11.0	18.9
54,000	125.5	8.0	7.7
52,000	354.0	6.0	14.3
41,000	1207.0	4.0	1.0

Vickers Hardness: As received - 348
After 1207 hours at 1200° F - 316

Alloy 16-25-6 - Cold Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	94,000
10	78,000
100	57,000
1000	42,000

COMMENTS SUPPLIED BY THE MANUFACTURER

(Supplied by The Timken Roller Bearing Co., Steel and Tube Division)

FORGEABILITY As this material possesses excellent high-temperature strength, it will be found to be very hard under the hammer at the forging temperature. A maximum forging temperature of 2050° F is recommended. The material should not be soaked at temperatures above 2000° F, although soaking below this temperature is permissible and is advisable if large sections have to be produced.

MACHINABILITY This material may be readily machined. Its machinability is at least equal to that of the austenitic 18-8 steel.

*Alloys 16-25-6 Annealed, 16-25-6 Hot Worked, and 16-25-6 "Cold" Worked are from the same ingot and differ only in processing.

Gamma Columbium - Annealed continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	66,000
10	54,000
100	44,000
1000	36,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY More consistent than 17W

MACHINABILITY About the same as 17W

*Alloys Gamma Columbium - Annealed, Gamma Columbium - Hot Rolled, Gamma Columbium - Hot Worked, and Gamma Columbium - "Cold" Worked are from the same heat and differ only in processing.

NACA

ALLOY Gamma Columbium - Hot Rolled* (A8736)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.40% C, 0.46% Si, 0.94% Mn, 15.08% Cr, 24.71% Ni, 4.39% Mo,
1.90% Cb, 0.015% S, 0.018% P, 0.036% N₂

TREATMENT Melted in electric arc furnace, 12,000 pound heat. Ingots
hammer cogged. Rolled at 2050/1860° F to a 3/4-inch square
bar. Stress relieved by soaking thru at 1200° F. Air cooled.

HARDNESS 198 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	111,750	38,500	52,500	25,000	34.0	33.5
	111,000	31,000	49,500	17,500	33.0	39.1
1200	79,500		36,500	22,500	16.0	20.6
	81,625		36,125	20,000	20.0	20.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
72,000	0.63	13.0	15.6
65,000	0.90	10.0	13.7
60,000	1.82	6.0	13.2
45,000	68.0	4.0	3.6
40,000	154.	6.0	7.3
31,000	1155.	10.0	14.5

Vickers Hardness: As received - 214
After 1155 hours at 1200° F - 237

Gamma Columbium - Annealed continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	68,000
10	56,000
100	43,000
1000	31,400

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forging properties are more consistent than those of 17W.

MACHINABILITY About the same as 17W.

*Alloys G-Cb and G-Cb HW are from the same heat and differ only in processing.

NACA

ALLOY Gamma Columbian - Hot Worked* (Rolled at 1700° F.)
(A8736)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION .40% C, .46% Si, .84% Mn, 15.03% Cr, 24.71% Ni,
4.39% Mo, 1.90% Cb, 0.036% N₂.

TREATMENT Melted in an electric arc furnace; 12,000 pound
heat. Forged and rolled at 2050/1860° F to
7/8-inch square bar. Heated 1 hour at 2100° F
and air cooled. Reheated to 1700° F and re-
duced in area 22.98% by rolling. Air cooled.
Stress relieved by heating through at 1200° F
and air cooled.

HARDNESS 239 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	119,250	72,000	91,000	55,000	21.0	38.5
	118,250	71,000	90,000	57,000	20.0	37.3
1200	84,000		69,500	40,000	20.0	38.5
	81,500		70,000	37,500	21.0	41.2

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
75,000	.23	20.0	41.8
64,000	2.52	15.0	41.8
50,000	42.0	16.0	39.8
48,000	83.0	16.0	31.3
44,000	271.0	15.0	38.9
39,000	617.0	14.0	23.4

Vickers Hardness: As received - 264
After 617 hours at 1200° F - 223

Gamma Columbium - Hot Worked (Rolled at 1700° F.) continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	68,000
10	58,000
100	48,000
1000	38,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY More consistent than 17W

MACHINABILITY About the same as 17W

*Alloys Gamma Columbium - Annealed, Gamma Columbium - Hot Rolled, Gamma Columbium - Hot Worked, and Gamma Columbium - "Cold" Worked are from the same heat and differ only in processing.

NACA

ALLOY Gamma Columbian - "Cold" Worked* (Rolled at 1200° F.)
(A8736)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.40% C, 0.46% Si, 0.84% Mn, 15.08% Cr, 24.71% Ni,
4.39% Mo, 1.90% Cb, 0.036% N₂.

TREATMENT Melted in electric arc furnace, 12,000 pound heat. Rolled
at 2050/1860° F to 7/8-inch square bar; then rolled at
1200° F to 22.1% reduction in area. Stress relieved by
soaking thru at 1200° F. Air cooled.

HARDNESS 333 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	160,250	115,000	146,000	75,000	12.0	28.3
	161,500	121,000	148,000	75,000	14.5	30.0
1200	110,875		100,000	47,500	6.0	10.7
	110,750		-----	-----	7.0	11.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
93,000	1.04	4.0	7.8
87,000	1.63	2.0	2.3
60,000	32.2	3.0	2.3
50,000	126.0	1.0	3.7
40,000	612	2.0	2.8

Vickers Hardness: As received - 342
After 612 hours at 1200° F - 300

Alloy Gamma Columbium - "Cold" Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	95,000
10	70,000
100	51,000
1000	37,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forging properties are more consistent than those of 17W.

MACHINABILITY About the same as 17W.

*Alloys G-Cb and G-Cb HW are from the same heat and differ only in processing.

NACA

ALLOY Non-Magnetic (B4018)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.73% C, 0.35% Si, 9.32% Mn, 3.96% Cr, 6.21% Ni, 0.28% Mo, 0.52% W, 0.19% Va

TREATMENT Melted in electric arc furnace, 24,000 pound heat. Ingots hammer clogged. Rolled at 2045/1855° F to 7/8-inch square bar. Rolled at 1200° F to 20.6% reduction in area. Stress relieved by soaking thru at 1200° F. Air cooled.

HARDNESS 333 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	168,000	111,250	131,500	85,000	14.5	14.7
	171,500	122,500	135,000	87,500	20.0	23.0
1200	80,000		78,000	45,000	1.5	6.7
	80,000		77,000	30,000	2.0	10.1

STRESS-RUPTURE DATA AT 1200° F*

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
40,000	3.40	1.0	0.5
30,000	16.75	0.5	1.0
25,000	71.3	2.0	2.8
20,000	268.	2.0	10.3

Vickers Hardness: As received - 351
After 268 hours at 1200° F - 351

Alloy Non-Magnetic continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	48,000
10	33,500
100	23,200
1000	16,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forges better than 17W.

MACHINABILITY More difficult to machine than 17W.

*Rupture test specimens were 0.300-inch diameter with 1-inch gage length.

NACA

ALLOY Hot Die Steel (E447)(A8657)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.24% C, 0.66% Si, 0.41% Mn, 6.04% Cr, 1.04% Ni, 6.14% Mo, 2.16% W, 0.23% Va.

TREATMENT Melted in arc furnace; 12,000 pound heat. Hammered and rolled to 3/4-inch rd. Heated to 2100° F for one hour and air cooled. Reheated to 1200° F for 72 hours and air cooled.

HARDNESS 287 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	139,000	86,300	96,000	70,000	14.0	29.1
	136,750	85,300	94,600	72,500	14.0	29.5
1200	47,400		37,500	10,000	36.0	77.4
	47,500		37,800	10,000	36.0	78.3

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
42,000	0.083	24.0	80.8
38,000	0.33	32.0	76.5
34,000	0.87	42.0	78.5

STRESS-RUPTURE PROPERTIES AT 1200° F

Sufficient data are not available to determine the rupture strengths as reported for other alloys.

Hot Die Steel (E447) continued

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Better than 17W

MACHINABILITY Better than 17W

NACA

ALLOY R1038 - Annealed* (R1568)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION .097% C, 0.80% Si, 0.77% Mn, 14.34% Cr, 6.79% Ni, 3.32% Mo

TREATMENT Melted in an induction furnace; 33 pound ingot. Hammer clogged 2075/1730° F to 2 by 2 inches. Hammer forged to 3/4-inch square bar. Heated 1 hour at 1850° F and air cooled.

HARDNESS Brinell 214

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	125,750	39,700	48,500	25,000	50.0	53.8
	126,800	41,000	50,200	27,500	54.0	56.7
1200	65,750		24,700	15,000	42.5	62.3
	68,300		24,300	12,500	45.0	61.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
60,000	.43	34.0	56.9
54,000	2.45	35.0	41.8
45,000	46.5	24.0	32.4
42,000	101.0	19.0	32.4
35,000	402.0	24.0	32.9

Vickers Hardness: As received - 224
After 402 hours at 1200° F - 354

Alloy R1038 - Annealed continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	57,000
10	52,000
100	42,000
1000	31,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Better than 17W

MACHINABILITY Better than 17W

*Alloys R1038 and R1038 - Annealed are from the same heat
and differ only in processing.

NACA

ALLOY R1038 - "Cold" Worked* (R1568)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.097% C, 0.80% Si, 0.77% Mn, 14.34% Cr, 6.79% Ni, 3.32% Mo

TREATMENT Melted in an induction furnace; 33 pound ingot. Hammer clogged to 2 by 2 inches at 2075/1730° F. Hot rolled 2070/1900° F to 7/8-inch square bar. Heated 1 hour at 1850° F and air cooled. Re-heated to 1200° F and reduced in area 23.02% by rolling. Stress relieved by heating through at 1200° F and air cooled.

HARDNESS 286 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	157,000	76,400	98,500	47,500	21.0	18.4
	163,000	81,400	99,600	50,000	22.0	15.6
1200	80,250		69,400	27,500	18.0	38.5
	80,000		68,750	22,500	18.0	41.6

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
72,000	.41	16.0	38.1
63,000	2.23	9.0	15.5
48,000	39.5	5.0	1.8
45,000	94.0	0.5	1.8
41,000	96.5	2.0	4.8
40,000	163.0	2.0	1.0
38,000	377.0	3.0	7.3

Vickers Hardness: As received - 302
After 377 hours at 1200° F - 359

Alloy R1038 - "Cold" Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	67,000
10	56,000
100	44,000
1000	34,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Better than 17W

MACHINABILITY Better than 17W

*Alloys R1038 - "Cold" Worked and R1038 - Annealed are from the same heat and differ only in processing.

NACA

ALLOY 18-14 S-Mo (A7480)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.057% C, 0.66% Si, 1.91% Mn, 18.12% Cr, 13.54% Ni, 2.85% Mo

TREATMENT Melted in electric arc furnace, 12,000 pound heat. Ingots hammer clogged. Rolled at 2055/1830° F to 7/8-inch square bar. Area reduced 23% by rolling at 1200° F. Stress relieved by soaking thru at 1200° F.

HARDNESS 244 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	112,500	84,000	98,000	67,500	30.0	66.0
	113,375	86,500	100,000	72,500	33.0	66.7
1200	67,750		60,000	37,500	28.0	52.7
	68,250		60,700	20,000	26.0	55.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
60,000	0.80	27.0	51.8
55,000	2.63	25.0	51.8
45,000	44.0	42.0	51.9
40,000	181.	14.0	44.7
36,000	270.	10.0	37.0
31,000	1026.	8.0	22.3

Vickers Hardness: As received -256
After 1026 hours at 1200° F - 237

Alloy 18-14 S-Mo continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	59,000
10	50,000
100	42,000
1000	31,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forges better than 17W.

MACHINABILITY Superior to 17W.

NACA

ALLOY 19-9 W-Mo (B7030)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.12% C, 0.40% Si, 0.60% Mn, 19.12% Cr, 8.56% Ni,
0.39% Mo, 1.49% W, 0.43% Cb, 0.40% TiTREATMENT Melted in electric arc furnace, 24,000 pound heat.
Ingots hammer cogged. Rolled at 2060/1825° F to 7/8-
inch square bar. Rolled at 1200° F to 23% reduction
in area. Stress relieved by soaking thru at 1200° F.
Air cooled.

HARDNESS 275 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	124,250	83,000	104,500	67,500	26.0	58.8
	121,625	75,000	101,500	50,000	27.5	57.4
1200	70,500		63,000	37,500	20.0	60.6
	71,125		67,500	40,000	20.0	60.6

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
65,000	0.35	14.0	63.3
60,000	2.52	18.0	64.0
55,000	84.0	20.0	53.6
52,000	125.	19.0	51.7
49,000	190.	14.0	30.3
42,000	661.	22.0	40.5

Vickers Hardness: As received - 290
After 661 hours at 1200° F - 296

Alloy 19-9 W-Mo continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	62,000
10	58,000
100	53,000
1000	40,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forges better than 17W.

MACHINABILITY Superior to 17W.

NACA

ALLOY 19-9W-Mo (R1802)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.09% C, 0.62% Si, 0.52% Mn, 18.62% Cr, 9.05% Ni,
0.36% Mo, 1.21% W, 0.44% Cb, 0.38% Ti, 0.06% N₂

TREATMENT Melted in an induction furnace; 33 pound ingot.
Forged at 2055/1300° F to 7/8-inch square bar.
Heated 1 hour at 2100° F and air cooled. Re-
heated to 1200° F and reduced in area 23.99%
by rolling. Stress relieved by heating through
at 1200° F and air cooled.

HARDNESS 234 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield Stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	110,500	70,000	85,000	57,500	33.0	55.0
	109,500	76,200	87,000	62,500	34.0	52.8
1200	69,000		63,100	42,500	17.5	50.0
	69,000		63,100	45,000	16.0	54.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
59,000	0.35	11.0	56.9
56,000	8.15	12.0	53.2
52,000	177.0	13.0	48.3
50,000	117.5	8.0	14.7
48,000	890.5	10.0	28.8
42,000	Discontinued*	2.0	4.9

*Not fractured after 2128 hours. The elongation and reduction of area values are for the unbroken specimen after the test was discontinued.

Vickers Hardness: As received - 259
After 2128 hours at 1200° F - 262

Alloy 19-9W-Mo (R1802) continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	58,000
10	54,500
100	52,000
1000	49,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Better than 17W.

MACHINABILITY Better than 17W.

NACA

ALLOY 19-9W-Mo (R1956)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.11% C, 0.56% Si, 0.55% Mn, 18.80% Cr, 8.54% Ni,
0.38% Mo, 1.27% W, 0.45% Cb, 0.39% Ti

TREATMENT Melted in an induction furnace; 33 pound ingot.
Hammer clogged at 2055/1300° F to 7/8-inch square
bars. Heated to 2000° F for 1 hour and air
cooled. Reheated to 1200° F and reduced in
area 25.95% by rolling. Stress relieved by
heating through at 1200° F and air cooled.

HARDNESS 251 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	114,400	61,000	89,500	36,000	33.5	53.3
	114,000	75,000	91,000	57,500	35.0	52.2
1200	72,700		63,500	32,500	18.0	53.8
	73,000		65,000	30,000	16.5	47.8
	73,125		64,000	35,000	17.5	47.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
65,000	0.38	9.0	57.7
60,000	5.93	12.0	42.8
55,000	71.0	11.0	37.9
50,000	199.0	10.0	23.4
42,000	973.0	6.0	10.2

Vickers Hardness: As received - 252
After 973 hours at 1200° F - 261

Alloy 19-9W-Mo (R1956) continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	64,000
10	59,000
100	54,500
1000	42,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Better than 17W.

MACHINABILITY Better than 17W.

NACA

ALLOY 19-9W-Mo HC-2 (R1957)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.21% C, 0.56% Si, 0.46% Mn, 18.86% Cr, 8.76% Ni,
0.46% Mo, 1.29% W, 0.51% Cb, 0.33% TiTREATMENT Melted in an induction furnace; 33 pound ingot.
Hammer cogged at 2055/1300° F to 7/8-inch square bars. Heated to 2000° F for 1 hour and air cooled.
Reheated to 1200° F and reduced in area 24.50% by rolling. Stress relieved by heating through at 1200° F and air cooled.

HARDNESS Brinell 302

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	137,850	95,500	112,500	77,500	31.0	54.4
	137,500	94,000	112,500	75,000	30.5	52.8
1200	77,250		72,500	32,500	11.5	39.8
	83,500		75,000	40,000	11.5	40.1
	82,875		75,000	45,000	14.5	41.0

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
78,000	0.30	12.0	47.3
68,000	5.27	6.0	25.6
60,000	157.0	2.0	3.6
55,000	293.0	2.0	1.8
50,000	777.5	3.0	1.8

Vickers Hardness: As received - 299
After 777.5 hours at 1200° F - 298

Alloy 19-9W-Mo HC-2 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	73,000
10	67,000
100	61,000
1000	48,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Better than 17W.

MACHINABILITY Better than 17W.

NACA

ALLOY 19-9W-MoM (R1803)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.26% C, 0.57% Si, 0.52% Mn, 18.95% Cr, 9.05% Ni,
1.22% Mo, 1.19% W, 0.29% Cb, 0.21% TiTREATMENT Melted in an induction furnace; 33 pound ingot.
Hammer forged at 2055/1300° F to 7/8-inch square
bars. Heated 1 hour at 2100° F and air cooled.
Reheated to 1200° F and reduced in area 21.35%
by rolling. Stress relieved by heating through
at 1200° F and air cooled.

HARDNESS 289 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	136,750	95,000	112,500	75,000	28.5	48.4
	140,750	95,000	115,000	75,000	29.0	48.1
1200	91,000		81,000	52,500	16.0	38.8
	87,750		77,500	52,500	15.5	39.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
78,000	1.30	10.0	28.3
73,000	3.13	9.0	25.0
60,000	202.0	3.0	7.3
55,000	383.0	2.0	6.1
50,000	1027.0	3.0	7.9

Vickers Hardness: As received - 319
After 1027 hours at 1200° F - 334

Alloy 19-9W-MoM continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	79,000
10	70,000
100	62,000
1000	50,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Better than 17W.

MACHINABILITY Better than 17W.

NACA

ALLOY 19-9W-Mo4 (E688)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.11% C, 0.58% Si, 0.57% Mn, 18.79% Cr, 8.27% Ni,
4.11% Mo, 2.58% W, 1.19% Cb

TREATMENT Melted in an electric arc furnace; 2000 pound heat.
Forged and rolled at 2045/1855° F to 13/16-inch
square bars. Heated at 2000° F and air cooled.
"Aged" 72 hours at 1200° F and air cooled.

HARDNESS 284 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	138,500	40,700	78,100	22,500	12.0	13.4
	139,750	43,750	81,000	25,000	11.0	13.4
1200	74,500		50,300	20,000	25.0	41.3
	72,800		48,750	22,500	24.5	37.9

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
64,000	.77	23.0	43.7
60,000	1.73	25.0	39.9
45,000	38.5	20.0	29.3
40,000	58.0	16.0	17.8
40,000	144.0	16.0	24.1
35,000	270.0	11.0	19.1

Vickers Hardness: As received - 296
After 270 hours at 1200° F - 355

Alloy 19-9W-Mo4 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	62,500
10	52,500
100	39,500
1000	29,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Better than 17W.

MACHINABILITY Better than 17W.

NACA

ALLOY 19-9W-Mo4M

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.40% C, 0.78% Si, 1.49% Mn, 18.86% Cr, 9.05% Ni,
4.08% Mo, 2.36% W, 1.01% Cb.TREATMENT Melted in an induction furnace; 33-pound ingot.
Forged 2035/1300° F to 7/8-inch square bar. Heated
1 hour at 2100° F and air cooled. Reheated to
1200° F and reduced in area 20% by rolling. Stress
relieved by heating through at 1200° F and air cooled.

HARDNESS 321 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.) 0.02% 0.2%		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
80	150,500*				14.0	31.4
1200	94,000*				12.0	36.4

*Tensile tests on 0.160-inch diameter bars.

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
85,000	.15	15.0	35.0
75,000	2.56	9.0	16.1
60,000	59.5	15.0	22.8
55,000	47.5	15.0	29.8
48,000	313.0	13.0	18.9

Vickers Hardness: As received - 332
After 313 hours at 1200° F - 327

Alloy 19-9W-Mo4M continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb./sq in.)</u>
1	78,000
10	70,000
100	54,000
1000	42,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Better than 17W.

MACHINABILITY Better than 17W.

NACA

ALLOY 4 (R1077)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.55% C, 0.82% Si, 0.62% Mn, 13.69% Cr, 19.46% Ni,
1.65% Mo, 1.07% Cb, 0.021% TaTREATMENT Melted in induction furnace; 33-pound ingot, 3 $\frac{3}{8}$
by 3 $\frac{3}{8}$ inches square. Hammered and rolled at
2090/1900° F to 7/8-inch square bar. Rolled at
1200° F to 21.4% reduction in area. Stress
relieved by soaking thru at 1200° F. Air cooled.

HARDNESS 300 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.) 0.02% 0.2%		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
80	160,000	119,000	139,000	82,500	9.5	23.5
1200	100,875		87,500	30,000	8.0	16.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
88,000	1.03	2.0	6.2
82,000	1.48	2.5	4.2
50,000	36.3	2.0	4.2
40,000	65.0	1.0	1.7
35,000	110.	2.0	2.4
30,000	337.	1.0	2.8

Vickers Hardness: As received - 301
After 337 hours at 1200° F - 283

Alloy 4 (R1077) continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	88,000
10	58,000
100	38,000
1000	24,700

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forges better than 17W.

MACHINABILITY Superior to 17W.

NACA

ALLOY 9 (R1572)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.21% C, 0.96% Si, 0.62% Mn, 13.04% Cr, 19.54% Ni,
10.50% Co, 6.17% Mo, 1.41% Cu.TREATMENT Melted in an induction furnace, 33-pound ingot.
Hammer cogged 2070/1750° F to 2 by 2 inches. Hot
rolled 2070/1900° F to 7/8-inch square bar. Heated
1 hour at 2100° F and air cooled. Reheated to
1200° F and reduced in area 23.45% by rolling.
Stress relieved by heating through at 1200° F and
air cooled.

HARDNESS 280 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	132,500	97,300	116,400	80,000	17.0	35.7
	131,500	95,000	117,700	77,500	16.0	35.7
1200	92,750		81,500	32,500	14.0	28.8
	90,500		81,000	32,500	12.0	26.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
80,000	0.60	16.0	34.9
71,000	1.45	16.5	34.9
50,000	111.0	6.0	7.3
45,000	241.5	4.0	2.6
38,000	608.5	6.0	2.3

Vickers Hardness: As received - 258
After 608.5 hours at 1200° F - 280

Alloy 9 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb./sq in.)</u>
1	76,000
10	65,000
100	51,000
1000	35,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat more difficult than 17W.

MACHINABILITY Somewhat more difficult than 17W.

NACA

ALLOY 9M (R1573)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.21% C, 1.03% Si, 0.66% Mn, 13.12% Cr, 19.11% Ni,
4.80% Mo, 1.23% Cb.TREATMENT Melted in an induction furnace, 33-pound ingot.
Hammer cogged 2075/1750° F to 2 by 2 inches. Hot
rolled 2070/1900, to 7/8-inch square bar. Heated
1 hour at 2100° F and air cooled. Reheated to
1200° F and reduced in area 23.62% by rolling.
Stress relieved by heating through at 1200° F and
air cooled.

HARDNESS 291 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	132,250	78,500	116,000	50,000	19.5	40.4
	132,000	96,800	117,600	70,000	18.0	41.3
1200	90,250		81,000	22,500	10.0	24.1
	90,500		81,900	22,500	11.0	26.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
78,000	.47	8.0	22.2
68,000	2.17	4.0	9.7
54,000	127.0	8.0	18.8
52,000	156.5	10.0	25.6
48,000	233.5	0	0
43,000	420.0	2.0	5.5

Vickers Hardness: As received 292
After 420 hours at 1200° F - 268

Alloy 9M continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	74,000
10	64,000
100	55,000
1000	36,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY About the same as 17W.

MACHINABILITY About the same as 17W.

NACA

ALLOY 5 (R1074)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.52% C, 0.94% Si, 2.12% Mn, 13.86% Cr, 19.33% Ni,
10.90% Co, 3.23% Mo, 0.91% Cb, 1.48% TaTREATMENT Melted in induction furnace; 33-pound ingot, $3\frac{3}{8}$ by $3\frac{3}{8}$ inches. Hammered and rolled at 2060/1905° F to 7/8-inch square bar. Rolled at 1200° F to 20.5% reduction in area. Stress relieved by soaking thru at 1200° F. Air cooled.

HARDNESS 333 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
1200	92,500		70,000	20,000	8.0	16.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
87,000	0.77	4.0	7.0
80,000	0.97	4.0	6.1
50,000	48.0	5.0	4.2
35,000	289.	4.0	3.7
30,000	758.	6.0	5.3

Vickers Hardness: As received - 323
After 758 hours at 1200° F - 283

Alloy 5 (R1074) continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	84,000
10	66,500
100	44,000
1000	28,300

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat more difficult to forge than 17W.

MACHINABILITY Somewhat more difficult to machine than 17W.

NACA

ALLOY 5M (R1565)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.53% C, 0.67% Si, 0.55% Mn, 13.24% Cr,
19.46% Ni, 11.14% Co, 2.73% Mo, 2.33% Cu.TREATMENT Melted in an induction furnace; 33-pound ingot.
Hammer cogged 2075/1720° F to 2 by 2 inches. Hot
rolled 2070/1900° F to 7/8-inch square bars.
Heated 1 hour at 2100° F and air cooled. Reheated
to 1200° F and reduced in area 20% by rolling.
Stress relieved by heating through at 1200° F and
air cooled.

HARDNESS 298 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.) 0.02% 0.2%	Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
80	151,500*			9.0	31.4
1200	99,500*			10.0	25.0

*Tensile tests on 0.160-inch diameter bars.

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
88,000	.15	13.0	36.9
76,000	2.08	6.0	13.8
58,000	23.5	10.0	18.9
50,000	66.5	7.0	6.7
45,000	74.0	12.0	8.4
42,000	174.5	6.0	6.2

Vickers Hardness: As received - 336
After 174.5 hours at 1200° F - 281

Alloy 5M continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	78,500
10	66,000
100	48,000
1000	31,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat more difficult than 17W.

MACHINABILITY Somewhat more difficult than 17W.

NACA

ALLOY 5MM (R1567)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.11% C, 0.45% Si, 1.51% Mn, 13.32% Cr, 19.48% Ni,
10.72% Co, 2.77% Mo, 1.25% Cb.TREATMENT Melted in an induction furnace; 33-pound ingot.
Hammer clogged 2075/1730° F to 2 by 2 inches. Hot
rolled 2070/1900° F to 7/8- by 7/8-inch square
bar. Heated 1 hour at 2100° F and air cooled.
Reheated to 1200° F and reduced in area 23.72% by
rolling. Stress relieved by heating through at
1200° F and air cooled.

HARDNESS 247 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	117,250	86,000	103,100	67,500	24.0	57.8
	118,750	87,400	103,750	70,000	25.0	58.0
1200	86,750		80,000	45,000	18.0	50.3
	86,250		82,100	47,500	18.0	54.4

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
81,000	0.20	10.0	46.9
72,000	4.42	4.0	14.3
50,000	67.0	2.0	8.5
45,000	100.0	2.0	1.3
38,000	234.5	2.0	0.5

Vickers Hardness: As received - 235

After 234.5 hours at 1200° F - 272

Alloy 5MM continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	76,000
10	70,000
100	45,000
1000	28,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat more difficult than 17W.

MACHINABILITY Somewhat more difficult than 17W.

NACA

ALLOY 1 (R1033)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.14% C, 1.16% Si, 1.59% Mn, 18.86% Cr, 15.36% Ni,
12.95% Co., 2.26% Mo, 1.06% Nb, 0.048% TaTREATMENT Melted in induction furnace; 33-pound ingot, 3³/₈
inches square. Hammered and rolled at 2065/1900° F
to 7/8-inch square bar. Then reduced in area 25.5%
by rolling at 1200° F. Stress relieved by soaking
thru at 1200° F. Air cooled.

HARDNESS Brinell 266

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.) 0.02% 0.2%		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
80	127,875	95,500	114,250	65,000	25.0	52.7
	123,500	95,000	116,000	65,000	25.0	53.0
1200	93,500		86,000	35,000	21.0	45.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
76,000	1.48	16.0	48.7
71,000	3.48	14.0	40.0
50,000	75.0	6.0	6.2
45,000	115.	2.0	3.0
40,000	175.	4.0	16.7
35,000	333.	4.0	6.9

Vickers Hardness: As received - 229
After 333 hours at 1200° F - 165

Alloy 1 (R1033) continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	78,000
10	66,000
100	46,000
1000	27,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat more difficult to forge than 17W.

MACHINABILITY Somewhat more difficult to machine than 17W.

NACA

ALLOY 1M (R1564)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.22% C, 0.95% Si, 0.52% Mn, 18.20% Cr, 15.15% Ni,
10.58% Co, 2.91% Mo, 1.25% Cu.TREATMENT Melted in an induction furnace; 33-pound ingot.
Hammer clogged 2075/1700° F to 2 by 2 inches. Hot
rolled 2070/1900° F to 7/8-inch square bar. Heated
1 hour at 2100° F and air cooled. Reheated to
1200° F and reduced in area 22.36% by rolling.
Stress relieved by heating through at 1200° F and
air cooled.

HARDNESS 296 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	140,500	106,000	125,000	85,000	23.5	41.9
	139,500	102,600	122,500	82,500	23.0	44.9
1200	95,500		82,600	22,500	17.5	39.8
	92,750		81,700	20,000	17.0	40.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
85,000	.17	26.0	52.7
72,000	1.10	16.0	44.7
58,000	91.0	8.0	16.7
55,000	156.0	6.0	10.9
50,000	204.0	4.0	4.8
45,000	486.0	4.0	1.8
32,000	Discontinued at 1021 hours.		

Vickers Hardness: As received - 267

After 486 hours at 1200° F - 284

Alloy 1M continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	74,500
10	65,000
100	57,000
1000	40,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat more difficult than 17W.

MACHINABILITY Somewhat more difficult than 17W.

NACA

ALLOY 8 (R1570)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.24% C, 1.30% Si, 0.62% Mn, 17.79% Cr, 14.82% Ni,
10.40% Co, 5.93% Mo, 1.35% Cb.TREATMENT Melted in an induction furnace, 33-pound ingot.
Hammer clogged 2075/1730° F to 2 by 2 inches. Hot
rolled 2070/1900° F to 7/8-inch square bar.
Heated 1 hour at 2100° F and air cooled. Re-
heated to 1200° F and reduced in area 22.30%
by rolling. Stress relieved by heating through
at 1200° F and air cooled.

HARDNESS 302 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	141,500	99,800	126,800	70,000	17.0	28.8
	140,500	103,000	127,200	72,500	15.0	33.4
1200	97,250		85,200	40,000	14.0	34.1
	97,000		81,500	35,000	13.5	33.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
84,000	.72	14.0	36.4
72,000	2.18	13.0	17.7
52,000	89.5	5.0	3.7
48,000	223.0	4.0	3.7
44,000	338.5	4.0	4.2
38,000	608.5	4.0	1.2

Vickers Hardness: As received - 314
After 608.5 hours at 1200° F - 320

Alloy 8 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	80,000
10	64,000
100	52,000
1000	34,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGTABILITY Somewhat more difficult than 17W.

MACHINABILITY Somewhat more difficult than 17W.

NACA

ALLOY 8M (R1571)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.23% C, 1.36% Si, 0.63% Mn, 17.79% Cr, 15.31% Ni, 5.97% Mo, 1.28% Cu.

TREATMENT Melted in an induction furnace, 33-pound ingot. Hammer clogged 2080/1730° F to 2 by 2 inches. Hot rolled 2070/1900° F to 7/8-inch square bar. Heated 1 hour at 2100° F and air cooled. Re-heated to 1200° F and reduced in area 22.42% by rolling. Stress relieved by heating through at 1200° F and air cooled.

HARDNESS 306 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	138,300	90,600	123,200	55,000	13.5	31.1
	140,000	101,000	128,000	62,500	16.0	31.4
1200	98,250		81,800	25,000	12.0	31.5
	98,000		84,700	25,000	13.5	33.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
84,000	0.45	15.0	41.3
75,000	1.47	10.0	22.3
50,000	158.0	5.0	9.7
45,000	219.5	6.0	4.9
38,000	468.0	3.0	1.8

Vickers Hardness: As received - 298
After 468 hours at 1200° F - 331

Alloy 8M continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	78,000
10	64,000
100	52,000
1000	31,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat more difficult than 17W.

MACHINABILITY Somewhat more difficult than 17W.

NACA

ALLOY 2 (R1034)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.22% C, 1.35% Si, 1.86% Mn, 18.77% Cr, 15.0% Ni,
19.46% Co, 2.23% Mo, 1.13% Cu, 0.92% Ta, 0.052% N₂.TREATMENT Melted in induction furnace, 33-pound ingot, 3 $\frac{3}{8}$ by
3 $\frac{3}{8}$ inches. Hammered and rolled at 2070/1895° F to
7/8-inch square bar. Then reduced 22% in area by
rolling at 1200° F. Stress relieved by soaking thru
at 1200° F. Air cooled.

HARDNESS 297 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	146,000	112,000	128,000	82,500	21.0	39.1
	148,875	108,000	131,500	80,000	21.0	36.6
1200	91,625				15.0	28.5
	91,850		82,000	15,000	18.0	35.0

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
82,000	0.49	17.0	30.8
72,000	1.25	14.0	26.1
55,000	93.5	24.0	42.7
50,000	177.	30.0	50.2
45,000	459.	18.0	49.2

Vickers Hardness: As received - 290
After 459 hours at 1200° F - 316

Alloy 2 (R1034) continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	77,000
10	65,000
100	54,000
1000	41,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat more difficult to forge than 17W.

MACHINABILITY Somewhat more difficult to machine than 17W.

NACA

ALLOY 2M (R2002)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.23% C, 1.17% Si, 1.80% Mn, 18.88% Cr, 14.55% Ni,
20.31% Co, 2.21% Mo, 2.20% Cb.TREATMENT Melted in an induction furnace, 33-pound ingot.
Hammer clogged at 2055/1300° F to 7/8-inch square
bar. Heated to 2000° F for 1 hour and air cooled.
Reheated to 1200° F and reduced in area 27.23%
by rolling. Stress relieved by heating through
at 1200° F and air cooled.

HARDNESS 277 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	142,850	97,500	121,000	72,500	23.0	49.8
	145,350	102,000	124,000	72,500	22.0	43.4
1200	102,000		89,000	50,000	14.0	40.7
	103,000		86,500	45,000	13.0	39.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
90,000	0.15	12.0	45.6
78,000	2.10	13.0	25.4
55,000	83.0	5.0	6.2
50,000	329.0	1.0	1.2
45,000	828.0	2.0	2.5

Vickers Hardness: As received - 297
After 828 hours at 1200° F - 315

Alloy 2M continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	81,000
10	72,000
100	56,000
1000	44,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat more difficult than 17W.

MACHINABILITY Somewhat more difficult than 17W.

NACA

ALLOY 2MM

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.23% C, 0.47% Si, 1.76% Mn, 18.96% Cr, 14.74% Ni,
20.42% Co, 2.09% Mo, 2.11% Cb.TREATMENT Melted in an induction furnace; 33-pound ingot.
Hammer cogged at 2055/1300° F to 7/8-inch square
bar. Heated to 2000° F for 1 hour and air cooled.
Reheated to 1200° F and reduced in area 25.61%
by rolling. Stress relieved by heating through
at 1200° F and air cooled.

HARDNESS 298 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	143,100	99,500	124,500	80,000	23.5	49.5
	144,700	99,500	125,000	77,500	23.5	48.7
1200	104,750		89,500	35,000	12.5	40.7
	99,250		89,500	35,000	14.0	35.0

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
90,000	0.20	10.0	43.8
80,000	1.35	10.0	28.2
60,000	38.5	2.0	1.8
55,000	251.0	3.0	3.8
50,000	556.5	2.0	1.3

Vickers Hardness: As received - 321
After 556.5 hours at 1200° F - 323

Alloy 2MM continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	81,000
10	68,000
100	57,000
1000	48,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat more difficult than 17W.

MACHINABILITY Somewhat more difficult than 17W.

NACA

ALLOY 6 (R1075)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.26% C, 1.44% Si, 2.14% Mn, 17.83% Cr, 24.73% Ni, 19.63% Co, 3.66% Mo, 1.51% Cb, 1.05% Ta, 0.071% N₂.TREATMENT Melted in induction furnace; 33 pound heat, 3 $\frac{3}{8}$ by 3 $\frac{3}{8}$ inches square. Hammered and rolled at 2090/1900° F to 7/8-inch square bar. Rolled at 1200° F to 22.6% reduction in area. Stress relieved by soaking thru at 1200° F. Air cooled.

HARDNESS 286-307 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	147,750	100,500	130,500	57,500	15.0	29.6
	147,875	115,000	134,500	87,500	13.0	30.1
1200	96,250		81,250	25,000	20.0	29.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
85,000	0.30	20.0	39.3
72,000	2.27	26.0	31.9
50,000	90.2	16.0	27.7
45,000	335.	15.0	19.0
40,000	1109.	12.0	23.9

Vickers Hardness: As received - 297

After 1109 hours at 1200° F - 309

Alloy 6 (R1075) continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	76,000
10	62,000
100	50,000
1000	40,200

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat more difficult to forge than 17W.

MACHINABILITY Somewhat more difficult to machine than 17W.

NACA

ALLOY 6M (R2000)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.31% C, 1.44% Si, 2.25% Mn, 17.88% Cr, 24.45% Ni,
20.75% Co, 3.16% Mo, 2.44% Cb.TREATMENT Melted in an induction furnace, 33-pound ingot.
Hammer cogged at 2055/1300° F to 7/8-inch square
bar. Heated to 2000° F for 1 hour and air cooled.
Reheated to 1200° F and reduced in area 26.09% by
rolling. Stress relieved by heating through at
1200° F and air cooled.

HARDNESS 317 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	157,000	113,500	140,000	82,500	12.0	31.8
	158,000	112,000	140,000	82,500	12.5	28.3
1200	103,750		83,000	35,000	11.0	23.4
	108,000		93,000	50,000	10.5	20.6

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
90,000	0.23	7.0	10.8
78,000	1.13	5.0	14.4
56,000	94.5	4.0	7.3
50,000	226.5	4.0	3.7
45,000	859.0	1.0	1.2

Vickers Hardness: As received - 316
After 859 hours at 1200° F - 309

Alloy 6M continued

STRESS--RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	81,000
10	71,000
100	56,000
1000	44,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat more difficult than 17W.

MACHINABILITY Somewhat more difficult than 17W.

NACA

ALLOY 6MM (R2001)

MANUFACTURER Universal-Cyclops Steel Corporation

COMPOSITION 0.31% C, 0.63% Si, 1.75% Mn, 17.78% Cr, 24.42% Ni,
20.49% Co, 3.25% Mo, 2.66% Cb.TREATMENT Melted in an induction furnace, 33-pound ingot.
Hammer clogged at 2055/1300° F to 7/8-inch square
bar. Heated to 2000° F for 1 hour and air cooled.
Reheated to 1200° F and reduced in area 24.82% by
rolling. Stress relieved by heating through at
1200° F and air cooled.

HARDNESS 321 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	156,500	106,000	113,500	72,500	17.0	38.2
	157,500	117,000	140,000	85,000	13.0	31.2
1200	112,000		97,500	37,500	12.0	29.2
	102,750		92,000	30,000	13.0	32.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of Area (%)
95,000	0.30	9.0	31.9
90,000	1.56	8.0	25.6
66,000	73.0	7.0	9.7
60,000	343.0	6.0	6.2
56,000	456.0	5.0	8.6
50,000	1552.0	4.0	7.2

Vickers Hardness: As received - 298
After 1552 hours at 1200° F - 316

Alloy 6MM continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	91,000
10	84,000
100	64,000
1000	52,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Somewhat more difficult than 17W.

MACHINABILITY Somewhat more difficult than 17W.

NACA

ALLOY H350

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.60% Si, 1.5% Mn, 15.0% Cr, 16.0% Ni,
16.0% Co, 3.0% MoTREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a 1 $\frac{1}{8}$ -inch round bar and then rolled
to a 3/4-inch round bar. Initial forging temperature-
2000 to 2100° F, final rolling temperature - 1350 to
1425° F. No subsequent heat treatment.

HARDNESS 285-295 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	130,000	83,000	105,250	62,500	21.0	39.1
	151,500	105,000	126,000	85,000	23.0	36.0
	137,250	90,000	112,000	57,500	18.0	44.3
1200	94,750		75,000	35,000	20.0	32.0
	91,125		71,250	35,000	18.0	34.4

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
85,000	0.01	22.0	41.5
70,000	0.67	22.0	41.3
60,000	3.05	29.0	36.0
48,000	75.5	26.0	26.7
40,000	202.	12.0	17.2
30,000	822.	30.0	34.0

Vickers Hardness: As received - 328
After 822 hours at 1200° F - 238

Alloy H350 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	68,000
10	56,000
100	46,000
1000	28,700

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

NACA

ALLOY 1073 - Annealed* (Union Carbide and Carbon Research Laboratories, Inc., Alloy H350)

MANUFACTURER Allegheny Ludlum Steel Corporation

COMPOSITION 0.32% C, 1.48% Mn, 15.21% Cr, 16.0% Ni, 15.93% Co, 2.94% Mo, 0.017% P, 0.021% S, 0.052% N₂.

TREATMENT Melted in an electric arc furnace and cast into a 9-inch ingot, forged at 2175° F. Required about 10 reheatings to bring ingot down to 3/4 inch square. Heated 1 hour at 2200° F and air cooled.

HARDNESS 207-199 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	104,000	34,000	50,000	20,000	42.5	47.5
	115,750	40,500	51,000	25,000	40.5	41.9
1200	82,500		32,500	25,000	19.5	21.6
	76,000		32,500	25,000	13.5	16.0

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
67,000	1.17	10.0	7.8
60,000	2.10	4.0	12.1
52,000	72.0	6.0	12.1
45,000	149.0	5.0	3.1
38,000	331.0	4.0	6.1

Vickers Hardness: As received - 211
After 331 hours at 1200° F - 261

Alloy 1073 - Annealed continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	68,000
10	58,000
100	49,000
1000	30,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys 1073 - Annealed and 1073 - "Cold" Worked are from the same heat and differ only in the processing following hot work.

NACA

ALLOY 1073 - "Cold" Worked* (Union Carbide and Carbon Research Laboratories, Inc. Alloy H350)

MANUFACTURER Allegheny Ludlum Steel Corporation

COMPOSITION 0.32% C, 1.45% Mn, 15.21% Cr, 16.0% Ni, 15.93% Co, 2.94% Mo, .017% P, .021% S, .052% N₂.

TREATMENT Melted in an electric arc furnace and cast into a 9-inch ingot, forged at 2175° F. Required about 10 reheatings to bring ingot down to 3/4-inch square bar. Forged at 1200°-1400° F for the last 5-10% reduction. Drawn back 6 hours at 1200° F.

HARDNESS 251-300 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	123,000	75,500	98,000	52,500	15.0	36.0
	146,250	87,500	115,500	62,500	17.0	33.1
1200	81,250		69,500	42,500	25.5	41.2
	74,250				21.0	49.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
66,000	1.00	28.0	51.8
60,000	1.87	22.0	44.7
45,000	59.0	22.0	34.0
40,000	281.0	6.0	14.3
36,000	554.0	20.0	38.0

Vickers Hardness: As received - 259
After 554 hours at 1200° F - 254

Alloy 1073 - "Cold" Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	66,000
10	53,500
100	43,000
1000	35,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys 1073 - Annealed and 1073 - "Cold" Worked are from the same heat and differ only in the processing following hot work.

NACA

ALLOY H351

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.60% Si, 1.5% Mn, 15.0% Cr, 16.0% Ni,
25.0% Co, 3.0% MoTREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a 1 $\frac{1}{8}$ -inch round bar and then
rolled to a 3/4-inch round bar. Initial forging tem-
perature - 2000 to 2100° F, final rolling temperature -
1350 to 1425° F. No subsequent heat treatment.

HARDNESS 250 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	124,750	62,500	83,700	47,000	32.0	41.9
	132,000	74,500	95,000	50,000	29.5	39.1
	129,500	75,200	91,500	50,000	34.0	45.2
1200	90,750		65,000	45,000	25.5	31.8
	90,850		59,500	37,500	27.5	32.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
82,000	0.63	23.0	36.0
76,000	1.70	16.0	25.5
55,000	19.8	28.0	36.0
40,000	167.5	18.0	25.1
30,000	1854.	6.0	12.1

Vickers Hardness: As received - 273
After 1854 hours at 1200° F - 261

Alloy H351 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	79,000
10	61,000
100	44,500
1000	32,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H357

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.60% Si, 1.5% Mn, 15.0% Cr, 16.0% Ni,
25.0% Co, 5.0% MoTREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a 1¹/₈-inch round bar and then
rolled to a 3/4-inch round bar. Initial forging
temperature - 2000 to 2100° F, final rolling tem-
perature - 1350 to 1425° F. No subsequent heat
treatment.

HARDNESS 258 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	133,250	68,500	92,500	45,000	25.5	19.9
	132,000	68,500	88,250	45,000	29.0	33.4
1200	102,000		64,500	37,500	21.0	17.7
	99,000		62,000	35,000	25.0	26.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
90,000	0.65	15.0	15.5
80,000	2.33	12.5	13.7
54,000	41.5	8.0	12.2
42,000	97.0	7.0	15.6
40,000	238.	12.0	12.2
30,000	1801.	12.0	19.0

Vickers Hardness: As received - 304
After 1801 hours at 1200° F - 264

Alloy H357 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	88,000
10	62,500
100	45,000
1000	32,400

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H479

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 15.0% Cr, 20.0% Ni, 20.0% Co, 5.0% Mo

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot was forged to a 3/4-inch round bar. Initial forging temperature - 2000 to 2100° F, final forging temperature - 1350 to 1425° F. No subsequent heat treatment.

HARDNESS 263 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	125,000	73,000	93,750	30,000	21.0	34.1
	126,750	74,000	94,700	30,000	23.0	36.0
1200	90,750		68,500	32,500	19.0	21.1
	90,000		68,000	32,500	24.0	29.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
80,000	1.67	10.0	25.6
70,000	7.38	7.0	8.5
50,000	45.0	5.0	4.2
37,000	422.	3.0	7.3
35,000	568.	6.0	10.2

Vickers Hardness: As received - 285
After 568 hours at 1200° F - 278

Alloy H479 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	86,000
10	62,000
100	45,000
1000	32,300

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H496

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 15.0% Cr, 25.0% Ni, 10.0% Co, 4.0% Mo,
2.0% Cb, 0.08% N₂.TREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a 3/4-inch round bar. Initial
forging temperature - 2000 to 2100° F, final forging
temperature - 1350 to 1425° F. No subsequent heat
treatment.

HARDNESS 233-224

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	116,000	59,400	78,500	47,500	31.0	52.4
	115,500	58,200	73,000	47,500	34.0	54.4
1200	83,000		54,000	35,000	21.0	24.9
	78,500		55,000	35,000	22.0	35.0

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
72,000	1.28	18.0	28.8
67,000	1.89	18.0	35.4
45,000	94.0	12.0	18.3
38,000	425.	6.0	8.5

Vickers Hardness: As received - 273
After 425 hours at 1200° F - 266

Alloy H496 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	74,500
10	58,000
100	44,000
1000	34,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H414

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 15.0% Cr, 25.0% Ni, 16.0% Co, 5.0% Mo

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot was forged to a $1\frac{1}{8}$ -inch round bar and then rolled to a $3/4$ -inch round bar. Initial forging temperature - 2000 to 2100° F, final rolling temperature - 1350 to 1425° F. No subsequent heat treatment.

HARDNESS 290 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	130,250	77,000	98,500	52,500	16.0	24.8
	130,250	82,000	102,500	57,500	7.0	10.7
1200	94,750		72,000	30,000	11.0	14.1
	91,250		72,500	25,000	19.0	28.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
92,000	0.85	10.0	14.4
85,000	2.35	13.0	28.8
53,000	71.5	6.0	5.4
45,000	239.	8.0	10.2
40,000	328.	6.0	6.6

Vickers Hardness: As received - 286
After 328 hours at 1200° F - 270

Alloy H414 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	90,000
10	75,500
100	54,000
1000	32,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H353

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.60% Si, 1.5% Mn, 15.0% Cr, 25.0% Ni,
16.0% Co, 2.0% Mo, 3.0% WTREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a $1\frac{1}{8}$ -inch round bar and then
rolled to a $3/4$ -inch round bar. Initial forging tem-
perature - 2000 to 2100° F, final rolling temperature -
1350 to 1425° F. No subsequent heat treatment.

HARDNESS 255 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	126,750	69,000	89,500	50,000	27.0	37.3
	129,375	75,000	95,000	57,500	26.0	37.6
1200	92,750		70,000	37,500	12.5	11.5
	90,750		65,000	37,500	12.0	13.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
82,000	0.12	18.0	21.2
70,000	0.55	18.0	21.0
60,000	2.73	22.0	28.7
42,000	69.0	20.0	26.7
35,000	153.	22.0	22.2
32,000	462.	13.0	9.0

Vickers Hardness: As received - 301
After 462 hours at 1200° F - 255

Alloy H353 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	66,000
10	53,000
100	39,000
1000	28,700

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H412

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 15.0% Cr, 25.0% Ni, 16.0% Co, 2.0% Mo, 3.0% W, 1.5% Cb

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot was forged to a $1\frac{1}{8}$ -inch round bar and then rolled to a $3/4$ -inch round bar. Initial forging temperature - 2000 to 2100° F, final rolling temperature - 1350 to 1425° F. No subsequent heat treatment.

HARDNESS 269-281 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	129,375	77,000	101,000	47,500	20.0	32.0
	132,500	85,500	108,500	62,500	16.5	32.4
1200	92,500		72,500	40,000	21.0	31.6
	91,625		74,000	37,500	19.0	28.6

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
80,000	1.35	21.0	31.9
74,000	2.15	10.0	12.1
50,000	42.0	7.0	10.8
42,000	238.	9.0	12.1
37,000	401.	8.0	11.0

Vickers Hardness: As received - 306
After 401 hours at 1200° F - 239

Alloy H412 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	83,000
10	60,000
100	44,000
1000	32,400

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H497

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 15.0% Cr, 25.0% Ni, 20.0% Co, 4.0% Mo,
2.0% Cb, 0.08% N₂.TREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a 3/4-inch round bar. Initial
forging temperature - 2000 to 2100° F, final forging
temperature - 1350 to 1425° F. No subsequent heat
treatment.

HARDNESS 245 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 1 in.)	Reduction of area (%)
		0.02%	0.2%			
80	123,250	61,500	81,600	47,500	24.0	34.0
	123,000	59,400	78,000	45,000	26.0	43.7
1200	77,500		65,000	37,500	24.0	41.5
	88,250		63,000	35,000	24.0	37.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
75,000	1.43	11.0	15.6
70,000	2.85	17.0	23.8
48,000	36.0	13.0	24.5
42,000	139.5	8.0	8.6
35,000	395.	10.0	13.8

Vickers Hardness: As received - 263
After 395 hours at 1200° F - 285

Alloy H497 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	80,000
10	59,000
100	43,000
1000	31,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H354

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.60% Si, 1.5% Mn, 15.0% Cr, 25.0% Ni,
25.0% Co, 2.0% Mo, 3.0% WTREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a 1½-inch round bar and then
rolled to a 3/4-inch round bar. Initial forging
temperature - 2000 to 2100° F, final rolling tem-
perature - 1350 to 1425° F. No subsequent heat
treatment.

HARDNESS 270 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	137,250	75,000	100,000	45,000	23.0	41.3
	137,250	82,500	103,000	57,500	20.0	37.9
1200	97,500		70,700	40,000	22.0	30.8
	105,000		70,000	35,000	16.0	17.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
95,000	0.18	14.0	23.3
90,000	0.27	12.0	15.5
75,000	1.88	12.0	15.5
50,000	55.5	16.0	13.7
42,000	114.5	15.0	15.7
40,000	113.	18.0	14.5
30,000	1238.	10.0	10.8

Vickers Hardness: As received - 325
After 1238 hours at 1200° F - 256

Alloy H354 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	80,000
10	64,000
100	44,000
1000	31,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H416

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.50% Si, 1.5% Mn, 15.0% Cr, 35.0% Ni,
16.0% Co, 5.0% MoTREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a $1\frac{1}{8}$ -inch round bar and then rolled
to a $3/4$ -inch round bar. Initial forging temperature -
2000 to 2100° F, final rolling temperature - 1350 to
1425° F. No subsequent heat treatment.

HARDNESS 269 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	124,500	60,500	81,000	42,500	23.0	31.3
	126,500	73,000	96,000	62,500	13.0	18.8
1200	90,000		68,500	47,500	12.0	12.5
	98,500		79,500	50,000	17.0	24.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 2 in.)	Reduction of area (%)
85,000	0.83	19.0	36.0
79,000	1.93	15.0	19.6
55,000	30.0	11.0	11.5
48,000	40.0	10.0	14.5
45,000	76.5	19.0	20.1
40,000	359.	9.0	12.1

Vickers Hardness: As received - 299
After 359 hours at 1200° F - 265

Alloy H416 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	82,000
10	62,000
100	46,500
1000	35,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H417

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.50% Si, 1.5% Mn, 15.0% Cr, 35.0% Ni,
16.0% Co, 3.0% Mo, 2.0% WTREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a 1 $\frac{1}{8}$ -inch round bar and then
rolled to a 3/4-inch round bar. Initial forging
temperature - 2000 to 2100° F, final rolling tem-
perature - 1350 to 1425° F. No subsequent heat
treatment.

HARDNESS 256 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	127,375	71,000	91,000	50,000	21.0	32.1
	127,000	72,500	93,000	50,000	21.0	36.8
1200	94,125		71,500	35,000	12.0	16.3
	96,125		75,900	30,000	13.0	15.6

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
85,000	1.18	18.0	27.2
78,000	3.01	12.0	12.6
48,000	75.0	14.0	16.7
40,000	212.	14.0	11.5

Vickers Hardness: As received - 309
After 212 hours at 1200° F - 265

Alloy H417 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	86,000
10	67,500
100	45,500
1000	30,500

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H419

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.50% Si, 1.5% Mn, 15.0% Cr, 35.0% Ni,
25.0% Co, 5.0% MoTREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a $1\frac{1}{8}$ -inch round bar and then
rolled to a $3/4$ -inch round bar. Initial forging
temperature - 2000 to 2100° F, final rolling tem-
perature - 1350 to 1425° F. No subsequent heat
treatment.

HARDNESS 272-270 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2 %			
80	139,500	78,750	102,000	55,000	19.0	32.7
	137,875	76,000	98,000	50,000	20.0	31.7
1200	96,750		71,500	42,500	24.0	27.7
	100,750		76,200	47,500	20.0	25.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
93,000	1.27	17.0	21.7
85,000	3.23	6.0	12.1
60,000	52.0	13.0	15.6
50,000	81.0	18.0	19.4
46,000	171.	11.0	12.1
40,000	404.	5.0	7.3

Vickers Hardness: As received - 307
After 404 hours at 1200° F - 283

Alloy H419 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	95,000
10	76,000
100	50,000
1000	33,700

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H418

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.50% Si, 1.5% Mn, 15.0% Cr, 35.0% Ni,
25.0% Co, 3.0% Mo, 2.0% WTREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a 1 $\frac{1}{8}$ -inch round bar and then
rolled to a 3/4-inch round bar. Initial forging
temperature - 2000 to 2100° F, final rolling tem-
perature - 1350 to 1425° F. No subsequent heat
treatment.

HARDNESS 273-272 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	141,250	85,000	108,500	62,500	21.0	36.1
	135,500	78,500	101,250	50,000	15.5	31.2
1200	99,375		77,800	37,500	13.5	13.1
	102,375		77,500	42,500	17.0	21.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
95,000	1.67	12.0	12.8
85,000	2.99	18.0	22.7
55,000	82.0	14.0	13.3
45,000	623.	6.0	7.8

Vickers Hardness: As received - 313
After 623 hours at 1200° F - 277

Alloy H418 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

Time for rupture (hr)	Stress (lb/sq in.)
1	99,000
10	74,000
100	56,000
1000	43,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H729

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.25% C, 16.0% Cr, 24.0% Ni, 3.0% Mo, 6.0% W,
.10% N₂.TREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a 3/4-inch round bar. Initial
forging temperature of about 2100° F, final forging
temperature about 1400° F. No subsequent heat
treatment.

HARDNESS 252 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	129,750	73,000	94,500	45,000	24.0	40.9
	126,250	63,000	88,200	42,500	20.0	35.7
1200	86,000		63,750	42,500	18.0	31.9
	84,500		65,000	42,500	20.0	36.3

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
74,000	0.55	18.0	26.2
67,000	1.62	10.0	12.8
48,000	45.5	11.0	12.8
43,000	128.5	16.0	38.0
36,000	599.0	14.0	13.2

Vickers Hardness: As received - 273
After 599 hours at 1200° F - 241

Alloy 4729 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	70,000
10	58,000
100	44,000
1000	34,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged with difficulty.

MACHINABILITY Metal turned without difficulty but was threaded with difficulty.

NACA

ALLOY H480

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 20.0% Cr, 20.0% Ni, 20.0% Co, 5.0% Mo

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot was forged to a 3/4-inch round bar. Initial forging temperature - 2000 to 2100° F, final forging temperature - 1350 to 1425° F. No subsequent heat treatment.

HARDNESS 266-277 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	135,000	71,500	102,500	35,000	18.0	32.1
	134,000	67,000	98,000	40,000	20.0	32.7
1200	93,125		72,500	42,500	18.0	30.8
	91,000		68,000	35,000	21.0	28.3

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
83,000	0.58	12.0	17.8
74,000	1.30	22.0	35.0
50,000	32.0	23.0	21.2
42,000	142.	18.0	29.3
37,000	363.	20.0	31.3

Vickers Hardness: As received - 307
After 363 hours at 1200° F - 291

Alloy H480 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	79,000
10	58,000
100	44,000
1000	32,400

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H355

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.60% Si, 1.5% Mn, 20.0% Cr, 25.0% Ni, 25.0% Co, 3.0% Mo

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot was forged to a $1\frac{1}{8}$ -inch round bar and then rolled to a $3/4$ -inch round bar. Initial forging temperature - 2000 to 2100° F, final rolling temperature - 1350 to 1425° F. No subsequent heat treatment.

HARDNESS 279 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	138,500	82,000	105,000	57,500	20.0	33.4
	138,000	79,000	101,750	57,500	23.0	36.3
1200	92,750		70,300	40,000	20.0	22.3
	92,875		68,000	35,000	19.0	27.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
90,000	1.15	22.0	27.7
82,000	2.76	20.0	25.0
50,000	96.0	--	8.1
40,000	455.	6.0	7.2

Vickers Hardness: As received -338
After 455 hours at 1200° F - 300

Alloy H355 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	91,000
10	70,000
100	50,000
1000	35,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

NACA

ALLOY H413

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.50% Si, 1.5% Mn, 20.0% Cr, 25.0% Ni, 25.0% Co,
3.0% Mo, 1.5% CbTREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a 1 $\frac{1}{8}$ -inch round bar and then rolled
to a 3/4-inch round bar. Initial forging temperature -
2000 to 2100° F, final rolling temperature - 1350 to
1425° F. No subsequent heat treatment.

HARDNESS 317 Brinell

TENSILE PROPERTIES

Temper- ature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	141,625	80,000	109,500	62,500	30.0	20.7
	136,500	77,500	101,000	52,500	18.0	27.8
1200	91,125		72,500	42,500	19.0	29.3
	94,250		76,500	40,000	21.0	29.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
90,000	0.98	22.0	20.6
85,000	2.40	18.0	20.7
60,000	36.0	10.0	15.6
48,000	93.0	17.0	13.2
40,000	435	8.0	8.5

Vickers Hardness: As received - 317
After 435 hours at 1200° F - 286

Alloy H413 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	90,000
10	72,000
100	50,000
1000	35,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORCEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H359

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.60% Si, 1.5% Mn, 20.0% Cr, 25.0% Ni, 25.0% Co, 2.0% Mo, 3.0% W

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot was forged to a $1\frac{1}{8}$ -inch round bar and then rolled to a $3/4$ -inch round bar. Initial forging temperature - 2000 to 2100° F, final rolling temperature - 1350 to 1425° F. No subsequent heat treatment.

HARDNESS 244 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	134,000	47,500	71,300	30,000	25.0	22.0
	138,250	68,500	90,000	45,000	20.5	18.8
	136,500	55,500	82,500	32,500	27.0	31.8
1200	94,000		61,250	37,500	16.0	15.2
	94,000		62,000	35,000	15.0	13.0

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
88,000	1.0	16.0	15.5
84,000	1.6	20.0	35.0
55,000	37.0	13.0	14.4
40,000	290.	11.0	13.3
30,000	1801.	5.0	18.6

Vickers Hardness: As received - 297
After 1801 hours at 1200° F - 289

Alloy H359 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	88,000
10	67,000
100	47,000
1000	32,800

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H439

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.50% Si, 1.5% Mn, 20.0% Cr, 30.0% Ni,
30.0% Co, 5.0% MoTREATMENT Melted in an induction furnace; 30 to 35 pound heat.
Ingot was forged to a 3/4-inch round bar. Initial
forging temperature - 2000 to 2100° F, final forging
temperature - 1350 to 1425° F. No subsequent heat
treatment.

HARDNESS 345-331 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	155,000	91,000	115,500	50,000	23.0	29.4
	169,500	103,750	146,000	50,000	15.0	27.8
	149,750	78,000	100,000	50,000	30.0	37.7
1200	102,375		77,600	37,500	10.0	12.1
	111,375		87,000	20,000	12.0	12.3

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
98,000	1.08	12.0	12.3
90,000	3.22	12.0	12.1
65,000	51.0	6.0	7.2
50,000	205.	9.0	10.3
44,000	453.	6.0	6.7

Vickers Hardness: As received - 355/396
After 453 hours at 1200° F - 326

Alloy H439 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	99,000
10	81,000
100	56,000
1000	38,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty

MACHINABILITY Metal turned and threaded without difficulty

NACA

ALLOY H630*

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.20% C, 15.0% Cr, 25.0% Ni, 4.0% Mo, 2.0% Cb, 0.10% N₂.

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot forged. Heated at 1850° F, air cooled. Reduced 31.98% by rolling at 1200° F to 3/4-inch square bar. Reheated for 3/4 hour at 1000° C (1832° F) and air cooled.

HARDNESS 170 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	96,500	33,000	45,500	20,000	39.0	55.7
	95,570	30,300	43,300	17,500	39.0	55.7
1200	67,000		30,000	17,500	36.5	53.8

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
59,000	0.42	36.0	59.3
52,000	4.98	14.0	42.8
40,000	61.0	13.0	22.3
37,000	154.5	15.0	13.8
34,000	433.0	10.0	26.2

Vickers Hardness: As received - 184
After 433 hours at 1200° F - 263

Alloy H630 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	59,000
10	47,000
100	38,000
1000	31,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys H630 and H631 are from separate heats made to the same composition and processed in the same way except for the final annealing treatment for H630.

NACA

ALLOY H631*

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.20% C, 15.0% Cr, 25.0% Ni, 4.0% Mo, 2.0% Cb, .10% N₂.

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot forged. Heated at 1850° F, air cooled. Reduced 33.41% by rolling at 1200° F to 3/4-inch square bar. Stress relieved by heating through at 1200° F, air cooled.

HARDNESS 256 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2 %			
80	123,250	87,500	107,800	55,000	17.5	39.9
	123,000	83,500	108,500	52,500	16.5	34.6
1200	84,500		77,800	52,500	16.0	39.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
76,000	0.47	18.0	35.0
66,000	1.48	17.0	43.2
40,000	93.5	8.0	27.1
36,000	208.0	3.0	3.7
32,000	531.0	3.0	8.5

Vickers Hardness: As received - 281
After 531 hours at 1200° F - 270

Alloy H631 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	69,500
10	53,000
100	40,000
1000	30,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys H630 and H631 are from separate heats made to the same composition and processed in the same way except for the final annealing treatment for H630.

NACA

ALLOY H624*

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 15.0% Cr, 16.0% Ni, 16.0% Co, 5.0% Mo.

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot forged. Heated at 1850° F; air cooled. Reduced 26.14% by rolling at 1200° F to 3/4-inch square bar. Reheated for 3/4 hour at 1000° C (1832° F) and air cooled.

HARDNESS 221 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	120,250	58,000	77,800	35,000	27.5	42.7
	120,250	56,000	77,000	35,000	27.5	42.1
1200	73,750		52,000	22,500	29.0	47.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
65,000	0.52	15.0	13.7
57,000	2.08	25.0	27.1
42,000	30.0	33.0	27.2
37,000	127.0	32.0	42.7
30,000	868.5	18.0	20.2

Vickers Hardness: As received - 245
After 868.5 hours at 1200° F - 235

Alloy H624 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	62,000
10	48,000
100	37,000
1000	29,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys H624 and H625 are from separate heats made to the same composition and processed in the same way except for the final annealing treatment for H624.

NACA

ALLOY H625*

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 15.0% Cr, 16.0% Ni, 16.0% Co, 5.0% Mo.

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot forged. Heated at 1850° F, air cooled. Reduced 31.76% by rolling at 1200° F to 3/4-inch square bar. Stress relieved by heating through at 1200° F air cooled.

HARDNESS 227 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	140,500	103,750	124,700	82,500	16.0	27.6
	139,000	103,750	124,500	75,000	18.5	35.1
1200	93,250		82,800	52,500	15.5	34.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
83,000	0.37	14.0	37.9
75,000	1.42	14.0	24.1
58,000	19.5	18.0	28.8
49,000	57.0	7.0	1.2
43,000	374.0	5.0	8.6

Vickers Hardness: As received - 296

After 374 hours at 1200° F - 292.

Alloy H625 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	77,000
10	61,000
100	49,000
1000	39,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys H624 and H625 are from separate heats made to the same composition and processed in the same way except for the final annealing treatment for H624.

NACA

ALLOY H626*

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 15.0% Cr, 25.0% Ni, 25.0% Co, 5.0% Mo.

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot forged. Heated at 1850° F, air cooled. Reduced 29.83% by rolling at 1200° F to 3/4-inch square bar. Reheated for 3/4 hour at 1000° C (1832° F) and air cooled.

HARDNESS 212 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	118,000	46,500	62,400	25,000	32.0	40.7
	115,250	44,800	58,100	30,000	24.5	23.8
1200	83,250		48,000	27,500	25.5	31.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
74,000	0.27	20.0	17.8
62,000	0.98	18.0	18.3
40,000	48.5	17.0	20.2
35,000	133.0	18.0	24.4
28,000	513.0	23.0	21.7

Vickers Hardness: As received - 234
After 513 hours at 1200° F - 235

Alloy H626 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	64,000
10	52,000
100	36,000
1000	25,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys H626 and H627 are from separate heats made to the same composition and processed in the same way except for the final annealing treatment for H626.

NACA

ALLOY H627*

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 15.0% Cr, 25.0% Ni, 25.0% Co, 5.0% Mo.

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot forged. Heated at 1850° F, air cooled. Reduced 23.45% by rolling at 1200° F to 3/4-inch square bar. Stress relieved by heating through at 1200° F, air cooled.

HARDNESS 300 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	151,000	113,500	136,250	87,500	15.0	30.9
	152,000	114,200	137,500	90,000	14.0	28.8
1200	107,000		89,500	50,000	10.0	19.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
92,000	0.33	16.0	31.8
80,000	1.60	12.0	17.8
50,000	83.0	6.0	9.2
42,000	267.0	4.0	9.7
37,000	359.0	4.0	2.9

Vickers Hardness: As received - 301
After 359 hours at 1200° F - 281

Alloy H627 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	83,000
10	70,000
100	49,000
1000	32,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys H626 and H627 are from separate heats melted to the same composition and processed in the same way except for the final annealing treatment for H626.

NACA

ALLOY H628*

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 15.0% Cr, 35.0% Ni, 25.0% Co, 5.0% Mo.

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot forged. Heated at 1850° F, air cooled. Reduced 25.65% by rolling at 1200° F to 3/4-inch square bar. Reheated for 3/4 hours at 1000° C (1832° F) and air cooled.

HARDNESS 228 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	122,000	47,800	59,500	32,500	29.0	29.7
	121,500	44,000	59,400	27,500	33.0	42.1
1200	82,250		45,500	32,500	17.5	31.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction in area (%)
72,000	0.87	15.0	17.3
65,000	1.18	9.0	14.3
46,000	36.0	12.0	21.2
38,000	123.5	16.0	14.9
30,000	441.0	16.0	17.3

Vickers Hardness: As received - 235
After 441 hours at 1200° F - 255

Alloy H628 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	69,000
10	59,000
100	39,000
1000	26,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged with difficulty.

MACHINABILITY Metal turned without difficulty, but was threaded with difficulty.

*Alloys H628 and H629 are from separate heats made to the same composition and processed in the same way except for the final annealing treatment for H628.

NACA

ALLOY H629*

MANUFACTURER Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 15.0% Cr, 35.0% Ni, 25.0% Co, 5.0% Mo.

TREATMENT Melted in an induction furnace; 30 to 35 pound heat. Ingot forged. Heated at 1850° F, air cooled. Reduced 30.81% by rolling at 1200° F to 3/4-inch square bar. Stress relieved by heating through at 1200° F, air cooled.

HARDNESS 325 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	160,500	122,500	145,000	95,000	12.0	25.3
	160,500	123,000	144,000	100,000	12.0	29.3
1200	112,500		100,750	50,000	10.5	24.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
95,000	0.50	13.0	24.7
85,000	2.33	17.0	23.3
55,000	66.5	8.0	12.1
48,000	156.0	3.0	2.4
40,000	437.5	2.0	8.5

Vickers Hardness: As received - 335
After 437.5 hours at 1200° F - 303

Alloy H629 continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	91,000
10	76,000
100	51,000
1000	34,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged with difficulty.

MACHINABILITY Metal turned without difficulty, but was threaded with difficulty.

*Alloys H628 and H629 are from separate heats made to the same composition and processed in the same way except for the final annealing treatment for H628.

NACA

ALLOY N153 - Annealed*

MANUFACTURER Universal-Cyclops Steel Corporation and Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.35% C, 0.52% Si, 1.76% Mn, 16.20% Cr, 14.98% Ni, 12.82% Co, 3.01% Mo, 2.13% W, 1.06% Cb, 0.07% N₂.

TREATMENT Melted in an electric arc furnace, 600 pound heat cast in 45-pound ingot. Hammer forged at 2075/1350° F to 3/4-inch square bar. Air cooled after 1 hour at 2100° F.

HARDNESS 207 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	120,000	37,500	58,000	20,000	39.0	46.6
	119,375	38,500	57,000	20,000	36.0	43.0
1200	82,500		33,000	22,500	24.0	23.0
	87,500		34,700	20,000	24.0	13.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
78,000	0.23	18.0	19.0
65,000	4.40	9.0	21.2
50,000	84.5	----	20.2
45,000	271.0	7.0	14.4
40,000	651.0	11.0	15.6

Vickers Hardness: As received - 238
After 651 hours at 1200° F - 263

Alloy N153 - Annealed continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	72,000
10	62,000
100	50,000
1000	38,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys N153 - Annealed, N153 - Hot Worked, and N153 - "Cold" Worked
are from the same heat and differ only in processing.

NACA

ALLOY N153 - Hot Worked*

MANUFACTURER Universal-Cyclops Steel Corporation and Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.38% C, 0.52% Si, 1.78% Mn, 16.20% Cr, 14.98% Ni, 12.82% Co, 3.01% Mo, 2.19% W, 1.06% Cb, 0.07% N₂.

TREATMENT Melted in an electric arc furnace, 600 pound heat, cast in 45-pound ingot. Hammer forged at 2075/1600° F to 7/8-inch square bar. Heated 1 hour at 2100° F and air cooled. Reheated to 1700° F and reduced in area 24.18% by rolling. Stress relieved by heating through at 1200° F and air cooled.

HARDNESS 296 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	142,500	97,500	121,800	75,000	17.5	36.6
	140,750	93,000	119,000	70,000	20.0	41.6
1200	92,750		82,500	45,000	16.5	42.2
	94,000		82,500	45,000	16.5	38.2

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
83,000	0.97	16.0	40.4
78,000	2.97	8.0	16.1
58,000	66.0	10.0	20.1
50,000	161.0	16.0	25.6
45,000	419.0	8.0	20.1

Vickers Hardness: As received - 318
After 419 hours at 1200° F - 277

Alloy N153 - Hot Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	83,000
10	73,000
100	54,000
1000	40,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys N153 - Annealed, N153 - Hot Worked, and N153 - "Cold" Worked are from the same heat and differ only in processing.

NACA

ALLOY N153 - "Cold" Worked*

MANUFACTURER Universal-Cyclops Steel Corporation and Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.38% C, 0.52% Si, 1.78% Mn, 16.20% Cr, 14.98% Ni, 12.82% Co, 3.01% Mo, 2.19% W, 1.06% Cb, .07% N₂.

TREATMENT Melted in an electric arc furnace, 600 pound heat, 45-pound ingot. Hammer forged at 2075/1600° F to 7/8-inch square bar. Heated 1 hour to 2100° F and air cooled. Reheated to 1200° F and reduced in area 23.15% by rolling. Stress relieved by heating through at 1200° F and air cooled.

HARDNESS 324 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	157,500	117,500	141,000	100,000	18.0	36.3
	157,250	112,500	140,500	95,000	17.5	35.7
1200	110,000		95,000	57,500	13.0	31.1
	104,750		88,750	50,000	12.0	27.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
90,000	0.95	4.0	13.8
84,000	4.30	4.0	5.5
62,000	67.0	10.0	14.3
54,000	216.0	5.0	9.7
45,000	723.0	4.0	10.9

Vickers Hardness: As received - 329
After 723 hours at 1200° F - 313

Alloy N153 - "Cold" Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	90,000
10	80,000
100	60,000
1000	43,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys N153 - Annealed, N153 - Hot Worked, and N153 - "Cold" Worked are from the same heat and differ only in processing.

NACA

ALLOY N154 - Annealed*

MANUFACTURER Universal-Cyclops Steel Corporation and Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.32% C, 0.61% Si, 1.58% Mn, 16.17% Cr, 23.95% Ni, 20.95% Co, 3.06% Mo, 2.20% W, 1.03% Cb, .07% N₂.

TREATMENT Melted in an electric arc furnace, 600 pound heat, cast in 45-pound ingot. Hammer forged at 2075/1340° F to 3/4-inch square bar. Heated 1 hour at 2100° F and air cooled.

HARDNESS 209 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	120,000	136,000	57,000	17,500	35.0	40.5
	119,000	38,200	54,500	17,500	36.5	44.1
1200	87,000		39,600	12,500	18.0	20.8
	89,000		41,500	20,000	21.0	21.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
80,000	0.18	16.0	18.9
70,000	1.35	11.0	16.7
50,000	92.5	12.0	18.4
40,000	320.0	12.0	20.0
35,000	1061.0	12.0	21.2

Vickers Hardness: As received - 238
After 1061 hours at 1200° F - 259

Alloy N154 - Annealed continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	72,000
10	62,000
100	48,000
1000	35,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys N154 - Annealed, N154 - Hot Worked, and N154 - "Cold" Worked are from the same heat and differ only in processing.

NACA

ALLOY N154 - Hot Worked*

MANUFACTURER Universal-Cyclops Steel Corporation and Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.32% C, 0.65% Si, 1.58% Mn, 16.17% Cr, 23.95% Ni, 20.95% Co, 3.06% Mo, 2.20% W, 1.03% Cb, 0.07% N₂.

TREATMENT Melted in an electric arc furnace, 600 pound heat, cast in 45-pound ingot. Hammer forged at 2075/1600° F to 7/8-inch square bars. Heated 1 hour at 2100° F and air cooled. Reheated to 1700° F and reduced in area 26.32% by rolling. Stress relieved by heating through at 1200° F and air cooled.

HARDNESS 298 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	144,000	98,750	122,000	77,500	17.0	31.5
	145,000	107,000	123,750	85,000	17.5	32.8
1200	98,500		85,000	47,500	15.0	31.5
	101,000		90,000	45,000	16.0	31.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
88,000	0.53	12.0	23.4
82,000	1.12	14.0	29.1
58,000	57.0	20.0	30.8
52,000	140.0	17.0	21.3
45,000	835.0	9.0	20.1

Vickers Hardness: As received - 297
After 835 hours at 1200° F - 277

Alloy N154 — Hot Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	83,000
10	68,000
100	54,000
1000	44,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys N154 — Annealed, N154 — Hot Worked, and N154 — "Cold" Worked are from the same heat and differ only in processing.

NACA

ALLOY N154 - "Cold" Worked*

MANUFACTURER Universal-Cyclops Steel Corporation and Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.32% C, 0.65% Si, 1.58% Mn, 16.17% Cr, 23.95% Ni, 20.95% Co, 3.06% Mo, 2.20% W, 1.03% Cb, 0.07% N₂.

TREATMENT Melted in an electric arc furnace, 600 pound heat, cast in 45-pound ingot. Hammer forged at 2075/1600° F to 7/8-inch square bars. Heated 1 hour at 2100° F and air cooled. Reheated to 1200° F and reduced in area 25.88% by rolling. Stress relieved by heating through at 1200° F and air cooled.

HARDNESS 331 Brinell.

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	164,000	124,000	147,500	105,000	14.0	29.1
	164,500	136,500	163,000	105,000	13.0	28.8
1200	110,500		98,000	55,000	11.5	25.8
	117,500		102,800	47,500	10.5	30.2

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
95,000	0.92	10.0	22.3
86,000	2.43	8.0	16.7
58,000	102.0	4.0	7.3
52,000	164.0	4.0	7.3
45,000	573.0	4.0	8.6

Vickers Hardness: As received - 321
After 573 hours at 1200° F - 289

Alloy N154 "Cold" Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	94,000
10	74,000
100	58,000
1000	42,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys N154 - Annealed, N154 - Hot Worked, and N154 - "Cold"
Worked are from the same heat and differ only in processing.

NACA

ALLOY N155 - Annealed*

MANUFACTURER Universal-Cyclops Steel Corporation and Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.32% C, 0.59% Si, 1.54% Mn, 21.08% Cr, 20.80% Ni, 20.54% Co, 3.00% Mo, 2.18% W, 0.98% Cb, 0.11% N₂.

TREATMENT Melted in an electric arc furnace, 600 pound heat, cast in 45-pound ingot. Hammer forged at 2075/1320° F to 3/4-inch square bar. Heated 1 hour at 2100° F, air cooled.

HARDNESS 220 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	127,500	37,000	63,500	25,000	37.0	37.5
	128,000	40,500	63,000	20,000	35.0	38.0
1200	87,250		42,600	22,500	18.0	16.9
			42,300	30,000	15.0	18.0

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
77,000	0.57	15.0	20.5
70,000	1.72	12.0	13.2
50,000	157.0	10.0	17.2
45,000	308.0	15.0	18.9
40,000	828.0	18.0	22.3

Vickers Hardness: As received - 242
After 828 hours at 1200° F - 285

Alloy N155 - Annealed continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	74,000
10	64,000
100	52,000
1000	39,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys N155 - Annealed, N155 - Hot Worked, and N155 - "Cold" Worked are from the same heat and differ only in processing.

NACA

ALLOY N155 - Hot Worked*

MANUFACTURER Universal-Cyclops Steel Corporation and Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.32% C, 0.59% Si, 1.54% Mn, 21.08% Cr, 20.80% Ni, 20.54% Co, 3.00% Mo, 2.18% W, 0.98% Cb, 0.11% N₂.

TREATMENT Melted in an electric arc furnace, 600 pound heat, cast in 45-pound ingot. Hammer forged at 2075/1600° F to 7/8-inch square bar. Heated 1 hour at 2100° F and air cooled. Reheated to 1700° F and reduced in area 21.73% by rolling. Stress relieved by heating through at 1200° F, air cooled.

HARDNESS 334 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	158,000	110,500	135,000	90,000	16.0	28.5
	160,500	108,000	138,500	85,000	17.0	28.8
1200	107,500		92,500	47,500	15.0	30.8
	106,500		93,750	52,500	15.0	28.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
90,000	1.00	10.0	34.0
84,000	3.27	14.0	29.8
62,000	74.0	12.0	22.3
54,000	212.0	3.0	12.1
50,000	426.5	6.0	10.9
45,000	1295.	4.0	10.9

Vickers Hardness: As received - 336
After 1295 hours at 1200° F - 311

Alloy N155 - Hot Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	90,000
10	76,000
100	59,000
1000	46,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys N155 - Annealed, N155 - Hot Worked, and N155 - "Cold" Worked are from the same heat and differ only in processing.

NACA

ALLOY N155 - "Cold" Worked*

MANUFACTURER Universal-Cyclops Steel Corporation and Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.32% C, 0.59% Si, 1.54% Mn, 21.08% Cr, 20.80% Ni, 20.54% Co, 3.00% Mo, 2.18% W, 0.98% Cb, 0.11% N₂.

TREATMENT Melted in an electric arc furnace, 600 pound heat, cast in 45-pound ingot. Hammer forged at 2075/1600° F to 7/8-inch square bar. Heated 1 hour at 2100° F and air cooled. Reheated to 1200° F and reduced in area 25.62% by rolling. Stress relieved by heating through at 1200° F, air cooled.

HARDNESS 349 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	167,000	125,000	150,500	105,000	13.0	29.8
	169,500	125,000	152,500	102,500	14.0	30.8
1200	117,000		98,750	52,500	12.0	24.8
	118,750		95,000	47,500	11.0	26.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
98,000	.88	8.0	13.3
88,000	3.32	6.0	6.2
62,000	130.0	4.0	6.2
56,000	443.0	4.0	8.5
54,000	202.5	2.0	1.3
50,000	352.5	5.0	3.7
45,000	1249.	2.0	9.7

Vickers Hardness: As received - 341
After 1249 hours at 1200° F - 310

Alloy N155 - "Cold" Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	99,000
10	80,000
100	63,000
1000	46,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged and rolled without difficulty.

MACHINABILITY Metal turned and threaded without difficulty.

*Alloys N155 - Annealed, N155 - Hot Worked, and N155 "Cold" Worked are from the same heat and differ only in processing.

NACA

ALLOY N156 - Annealed*

MANUFACTURER Universal-Cyclops Steel Corporation and Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.33% C, 0.57% Si, 1.48% Mn, 15.66% Cr, 33.23% Ni, 23.69% Co, 3.02% Mo, 2.10% W, 1.03% Cb, 0.04% N₂.

TREATMENT Melted in an electric arc furnace, 600 pound heat, cast in 45-pound ingot. Hammer forged at 2075/1340° F to 3/4-inch square bar. Heated 1 hour at 2100° F and air cooled.

HARDNESS 208 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	124,000	37,500	57,000	20,000	37.0	37.8
	122,750	37,500	56,500	25,000	35.0	44.1
1200	89,000		41,000	27,500	16.0	19.3
	87,250		43,000	32,500	15.0	16.1

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
77,000	1.33	12.0	18.2
70,000	5.43	10.0	12.5
50,000	90.0	16.0	23.5
40,000	333.0	9.0	13.2
30,000	1885.0	7.0	14.8

Vickers Hardness: As received - 238
After 1885 hours at 1200° F - 264

Alloy N156 - Annealed continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	79,000
10	67,000
100	49,000
1000	33,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged with difficulty.

MACHINABILITY Metal turned without difficulty but threaded with difficulty.

*Alloys N156 - Annealed, N156 - Hot Worked, and N156 - "Cold" Worked are from the same heat and differ only in processing.

NACA

ALLOY N156 - Hot Worked*

MANUFACTURER Universal-Cyclops Steel Corporation and Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.33% C, 0.57% Si, 1.48% Mn, 15.66% Cr, 33.23% Ni, 23.69% Co, 3.02% Mo, 2.10% W, 1.03% Cb, 0.04% N₂.

TREATMENT Melted in an electric arc furnace, 600 pound heat, cast in 45-pound ingot. Hammer forged at 2075/1600° F to 7/8-inch square bar. Heated 1 hour at 2100° F and air cooled. Reheated to 1700° F and reduced in area 26.32% by rolling. Stress relieved by heating through at 1200° F and air cooled.

HARDNESS 303 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	146,250	105,500	123,000	82,500	18.5	36.0
	148,000	103,500	124,000	82,500	18.5	36.0
1200	106,625		92,500	42,500	16.0	29.5

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
90,000	0.92	12.0	23.8
84,000	2.43	14.0	29.3
60,000	66.0	20.0	24.9
52,000	171.00	11.0	24.5
45,000	810.0	3.0	8.5

Vickers Hardness: As received - 283
After 810 hours at 1200° F - 291

Alloy N156 - Hot Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	91,000
10	72,000
100	56,000
1000	44,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged with difficulty.

MACHINABILITY Metal turned without difficulty but threaded with difficulty.

*Alloy N156 - Annealed, N156 - Hot Worked, and N156 - "Cold" Worked are from the same heat and differ only in processing.

NACA

ALLOY N156 - "Cold" Worked*

MANUFACTURER Universal-Cyclops Steel Corporation and Union Carbide and Carbon Research Laboratories, Inc.

COMPOSITION 0.33% C, 0.57% Si, 1.48% Mn, 15.66% Cr, 33.23% Ni, 23.69% Co, 3.02% Mo, 2.10% W, 1.03% Cb, 0.04% N₂.

TREATMENT Melted in an electric arc furnace, 600 pound heat, cast in 45-pound ingot. Hammer forged at 2075/1600° F to 7/8-inch square bar. Heated 1 hour at 2100° F and air cooled. Reheated to 1200° F and reduced in area 24.24% by rolling. Stress relieved by heating through at 1200° F and air cooled.

HARDNESS 338 Brinell

TENSILE PROPERTIES

Temperature (°F)	Tensile strength (lb/sq in.)	Yield stress (lb/sq in.)		Proportional limit (lb/sq in.)	Elongation (% in 2 in.)	Reduction of area (%)
		0.02%	0.2%			
80	168,750	130,500	153,800	107,500	14.5	33.7
	168,000	123,000	149,000	102,500	13.0	29.5
1200	119,750		110,000	67,500	10.5	22.7

STRESS-RUPTURE DATA AT 1200° F

Stress (lb/sq in.)	Time for rupture (hr)	Elongation (% in 1 in.)	Reduction of area (%)
98,000	1.10	10.0	23.3
89,000	3.38	10.0	21.8
60,000	78.0	5.0	8.6
53,000	236.0	4.0	6.2
45,000	770.0	2.0	7.3

Vickers Hardness: As received - 351
After 770 hours at 1200° F - 320

Alloy N156 — "Cold" Worked continued

STRESS-RUPTURE PROPERTIES AT 1200° F
(Estimated from plot of test data)

<u>Time for rupture (hr)</u>	<u>Stress (lb/sq in.)</u>
1	99,000
10	78,000
100	59,000
1000	44,000

COMMENTS SUPPLIED BY THE MANUFACTURER

FORGEABILITY Forged with difficulty.

MACHINABILITY Metal turned without difficulty but threaded with difficulty.

*Alloys N156 — Annealed, N156 — Hot Worked, and N156 — "Cold" Worked are from the same heat and differ only in processing.

Designation	N153			N154			N155			N156		
	Ann.	NW	CW	Ann.	NW	CW	Ann.	NW	CW	Ann.	NW	CW
C	.36			.32			.36			.33		
Si	.52			.45			.49			.47		
Mn	1.06			1.56			1.64			1.48		
Cr	16.20			16.17			21.06			20.80		
Ni	14.98			23.99			23.99			33.23		
Co	12.82			20.95			20.94			23.49		
Mo	3.01			3.06			3.00			3.02		
W	2.19			2.20			2.18			2.10		
Fe	1.06			1.03			.98			1.03		
N	.07			.07			.11			.04		

660 Lb. Arc Furnace Melts
45 Lb. 3" x 3" Ingots

Hammer Forged at 2075 to 1800°F. to Indicated Sizes (Sq. bars)
3/4" Finishing Temperature of 1400°F. was 1340°F.

1 Hr. at 2100°F., Air Cooled

Rolling: Rolled at 2100°F. to 1800°F. at 1100°F. 1200°F.
24.0% 23.5% 23.0% 22.5% 22.0%
at at at at at
1100°F. 1200°F. 1300°F. 1400°F. 1500°F.

Heat Treatment: Heated at 1200°F. 1300°F. 1400°F. 1500°F. 1600°F. 1700°F. 1800°F. 1900°F. 2000°F. 2100°F. 2200°F. 2300°F. 2400°F. 2500°F. 2600°F. 2700°F. 2800°F. 2900°F. 3000°F. 3100°F. 3200°F. 3300°F. 3400°F. 3500°F. 3600°F. 3700°F. 3800°F. 3900°F. 4000°F. 4100°F. 4200°F. 4300°F. 4400°F. 4500°F. 4600°F. 4700°F. 4800°F. 4900°F. 5000°F. 5100°F. 5200°F. 5300°F. 5400°F. 5500°F. 5600°F. 5700°F. 5800°F. 5900°F. 6000°F. 6100°F. 6200°F. 6300°F. 6400°F. 6500°F. 6600°F. 6700°F. 6800°F. 6900°F. 7000°F. 7100°F. 7200°F. 7300°F. 7400°F. 7500°F. 7600°F. 7700°F. 7800°F. 7900°F. 8000°F. 8100°F. 8200°F. 8300°F. 8400°F. 8500°F. 8600°F. 8700°F. 8800°F. 8900°F. 9000°F. 9100°F. 9200°F. 9300°F. 9400°F. 9500°F. 9600°F. 9700°F. 9800°F. 9900°F. 10000°F.

Designation	N153			N154			N155			N156		
	Ann.	NW	CW	Ann.	NW	CW	Ann.	NW	CW	Ann.	NW	CW
C	.36			.32			.36			.33		
Si	.52			.45			.49			.47		
Mn	1.06			1.56			1.64			1.48		
Cr	16.20			16.17			21.06			20.80		
Ni	14.98			23.99			23.99			33.23		
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Heat Treatment: Heated at 1200°F. 1300°F. 1400°F. 1500°F. 1600°F. 1700°F. 1800°F. 1900°F. 2000°F. 2100°F. 2200°F. 2300°F. 2400°F. 2500°F. 2600°F. 2700°F. 2800°F. 2900°F. 3000°F. 3100°F. 3200°F. 3300°F. 3400°F. 3500°F. 3600°F. 3700°F. 3800°F. 3900°F. 4000°F. 4100°F. 4200°F. 4300°F. 4400°F. 4500°F. 4600°F. 4700°F. 4800°F. 4900°F. 5000°F. 5100°F. 5200°F. 5300°F. 5400°F. 5500°F. 5600°F. 5700°F. 5800°F. 5900°F. 6000°F. 6100°F. 6200°F. 6300°F. 6400°F. 6500°F. 6600°F. 6700°F. 6800°F. 6900°F. 7000°F. 7100°F. 7200°F. 7300°F. 7400°F. 7500°F. 7600°F. 7700°F. 7800°F. 7900°F. 8000°F. 8100°F. 8200°F. 8300°F. 8400°F. 8500°F. 8600°F. 8700°F. 8800°F. 8900°F. 9000°F. 9100°F. 9200°F. 9300°F. 9400°F. 9500°F. 9600°F. 9700°F. 9800°F. 9900°F. 10000°F.

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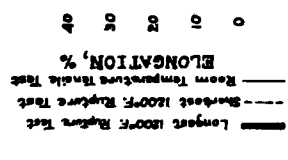
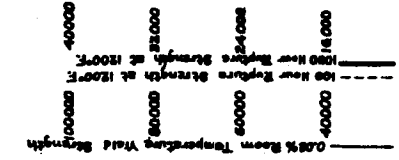
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STRESS, POUNDS PER SQUARE INCH



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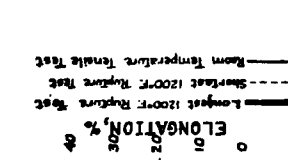
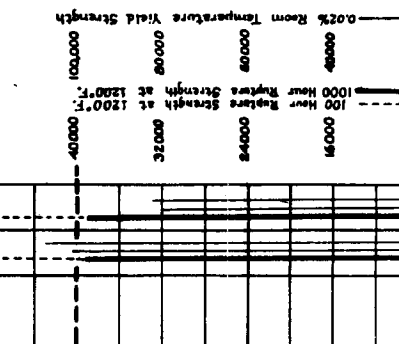


Figure 1 COMPARISON OF THE COMPOSITIONS, FABRICATION PROCEDURES, AND PROPERTIES OF THE ALLOYS SUBMITTED BY THE INDICATED MANUFACTURERS

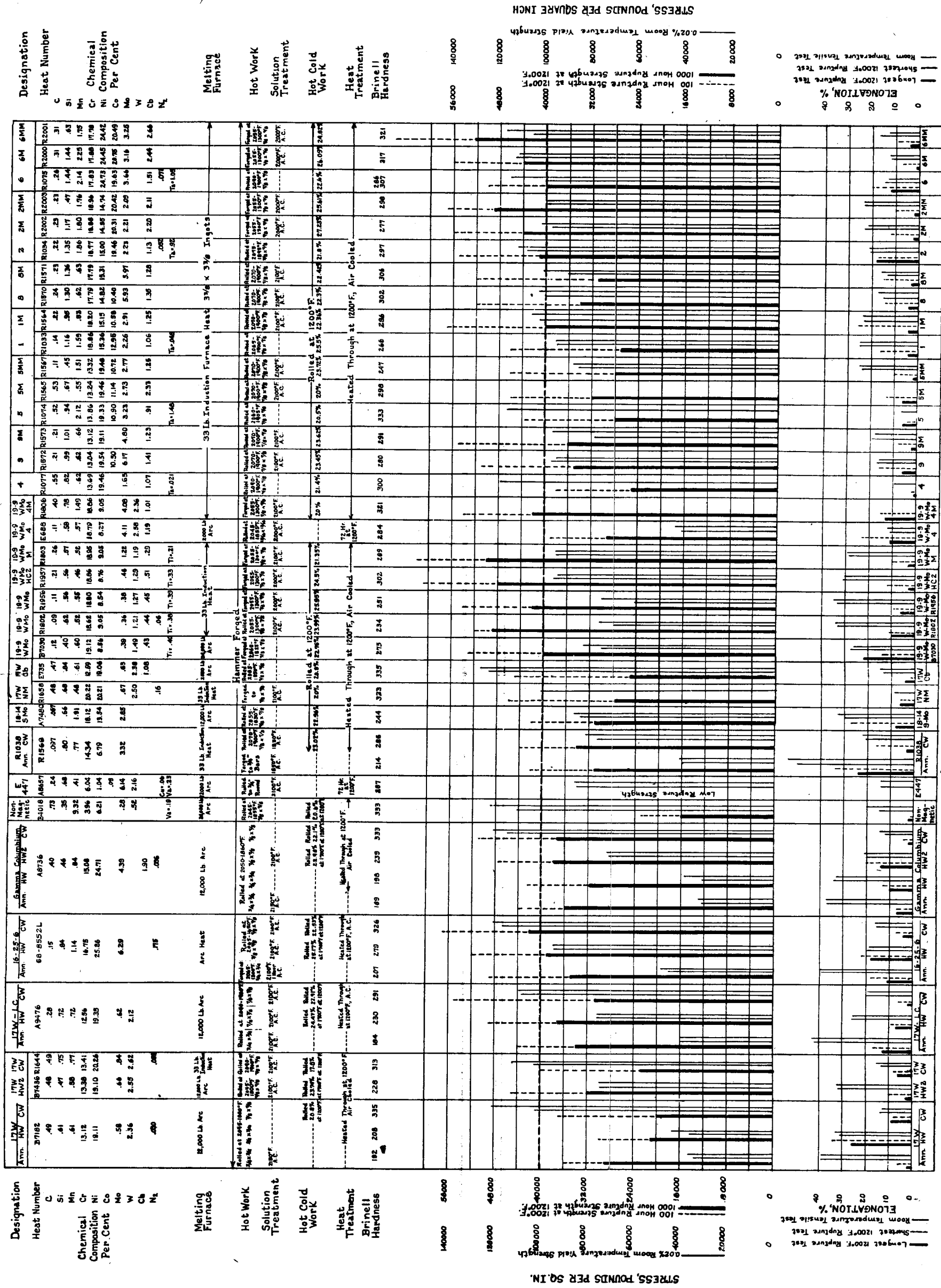


Figure 2. COMPARISON OF THE COMPOSITIONS, FABRICATION PROCEDURES, AND PROPERTIES OF THE ALLOYS SUBMITTED BY THE UNIVERSAL-CYCLOPS STEEL CORPORATION

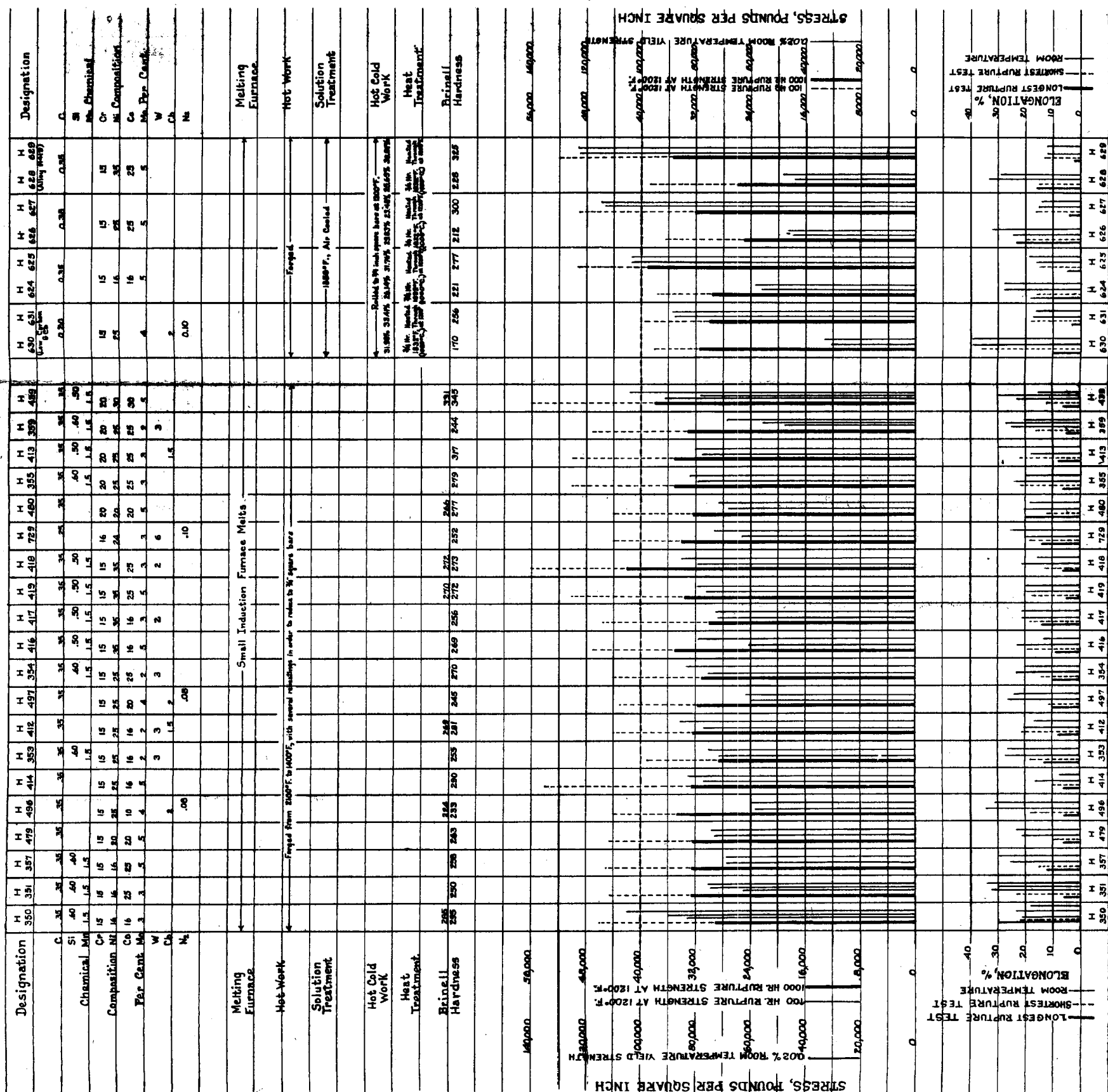
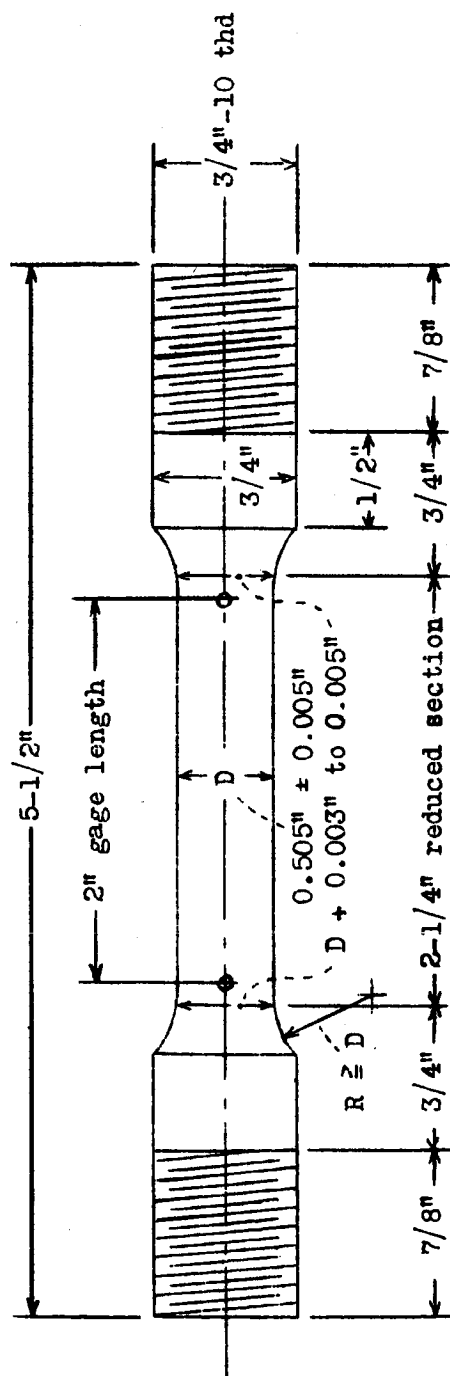
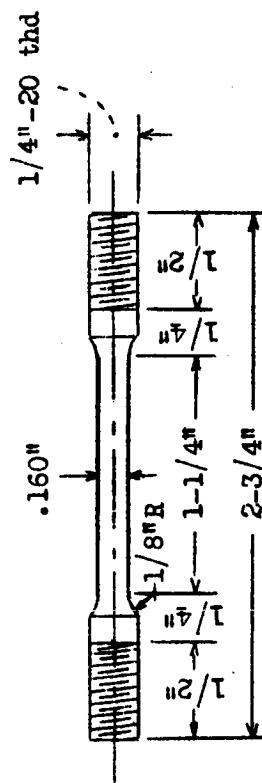


Figure 3. COMPARISON OF THE COMPOSITIONS, FABRICATION PROCEDURES AND PROPERTIES OF THE ALLOYS SUBMITTED BY THE UNION CARBIDE AND CARBON RESEARCH LABORATORIES. INC.



Tensile test specimen



Rupture test specimen

Figure 4.- Dimensions of tensile and rupture test specimens.

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TITLE: Physical Data on Certain Alloys for High Temperature Applications

AUTHOR(S) : White, A. E.; Freeman, J. W.; Rote, F. B.
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ABSTRACT:

The physical properties of 120 samples of metal alloys, representing 66 different compositions are discussed in regard to their suitability as turbosupercharger wheel materials. Data include chemical composition, fabrication procedure, tensile-test and hardness values at room temperature, and tensile and rupture-test characteristics at 1200° F. Sheets give chemical analyses, processing procedures, hardness values, yield strengths at room temperature and stresses for rupture in 100 and 1000 hours at 1200° F. of various alloys, thus permitting comparison of properties.

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